



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification 6 :</b>  <b>H05H</b>	<b>A2</b>	<b>(11) International Publication Number:</b> <b>WO 97/16946</b>  <b>(43) International Publication Date:</b> 9 May 1997 (09.05.97)									
<b>(21) International Application Number:</b> PCT/US96/17970  <b>(22) International Filing Date:</b> 31 October 1996 (31.10.96)  <b>(30) Priority Data:</b> <table border="0"> <tr> <td>08/551,123</td> <td>31 October 1995 (31.10.95)</td> <td>US</td> </tr> <tr> <td>08/551,122</td> <td>31 October 1995 (31.10.95)</td> <td>US</td> </tr> <tr> <td>08/551,131</td> <td>31 October 1995 (31.10.95)</td> <td>US</td> </tr> </table>  <b>(71) Applicant:</b> ARAKHNE TECHNOLOGY, INC. [US/US]; Building II, Suite 300, 1250 Capital of Texas Highway S., Austin, TX 78746 (US).  <b>(72) Inventor:</b> AUM, Paul, Kwangsup; 5109 Cuesta Verde, Austin, TX 78746 (US).  <b>(74) Agents:</b> CULBERTSON, Russell, D. et al.; Shaffer & Culbert- son, Building 1, Suite 360, 1250 Capital of Texas Highway S., Austin, TX 78746 (US).		08/551,123	31 October 1995 (31.10.95)	US	08/551,122	31 October 1995 (31.10.95)	US	08/551,131	31 October 1995 (31.10.95)	US	<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>Without international search report and to be republished          upon receipt of that report.</i>
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<b>(54) Title:</b> UNIFORM PLASMA GENERATION, FILTER, AND NEUTRALIZATION APPARATUS AND METHOD											
<b>(57) Abstract</b>  A system (30, 120, 140, 200, 250, 300, 350, 400, 450) and method (550; 600, 700) for generating, filtering, and neutralizing surface treating plasma (38) within a process chamber (36) to allow a uniform plasma to surface treat a substrate (40). A plurality of coil elements (46) are operably coupled to form a plurality of effective coils (47), the effective coils (47) adjacently spaced apart to form a coil layer (32). A drive element (34) may be coupled to coil elements (46) to induce effective closed loop currents (48) in the effective coils (47) to induce magnetic fields (50, 52) at each effective coil (47). The coil elements (46) may also simply be terminated such that the application of plasma (38) induces the magnetic fields (50, 52) at the effective coil. The magnetic fields (50, 52) may be induced to generate a plasma (38), to confine plasma away from hardware, to filter a plasma, and to neutralize plasma.											

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## UNIFORM PLASMA GENERATION, FILTER, AND NEUTRALIZATION APPARATUS AND METHOD

### Technical Field of the Invention

5           This invention relates generally to the processing and manufacture of substrates and more particularly to the generation, filtering, and neutralization of a uniform surface treating plasma within a process chamber.

### Background of the Invention

10           Semiconductor chips as well as various other devices such as flat panel displays are manufactured in a semiconductor manufacturing process. In the manufacture of an integrated circuit or flat panel display, semiconductor processes fabricate circuit elements on a substrate in a manner to create an operational circuit. Typically, the manufacturing process is performed in a clean room within process chambers. After circuit elements are  
15           fabricated on a substrate, the substrate is removed from the process chamber, packaged, installed in products, and sold for its intended use. The use of increasingly advanced manufacturing processes has substantially reduced the size of individual circuit elements and allowed the fabrication of millions of microscopic circuit elements on each substrate section. In this fashion, the functionality of integrated circuits has dramatically increased.

20           The fabrication of circuit elements on a substrate includes the repetition of four basic process steps. In a first process step, the characteristics of a surface layer of the substrate are selectively altered in a deposition process and/or a diffusion process. Typically, semiconductive elements are formed in a surface layer of the substrate that has been altered in the deposition/diffusion process step. Thus, the first step of deposition or  
25           diffusion typically creates transistors, diodes, resistors, and other semiconductive devices.

          In a deposition process, material is deposited upon the substrate. The material may include polycrystalline-silicon, metal, dielectric, nitrate, or other materials that will affect the operational characteristic of the substrate. By the application of material on the surface of the substrate, boundaries, connections, insulation layers, and other structures may be

formed on the substrate. However, in the deposition process itself, a uniform layer of material is generally laid down on the substrate.

In a diffusion process, the substrate is placed in a furnace or chamber wherein the properties of the surface of the substrate are altered. In one common diffusion process, an undoped substrate is ion implanted and annealed at high temperatures to a P-type or an N-type material, depending upon the process. In another common diffusion process, silicon is heated in a furnace so that the silicon atoms of the substrate combine with oxygen to form silicon dioxide on the substrate's surface.

After the deposition or diffusion step, a photolithographic step follows. In a typical photolithographic step, a photoresist layer is laid uniformly on the surface of the substrate. As is known in the art, the properties of the photoresist change substantially when exposed to light during an exposure process. In the exposure process, the photoresist is selectively exposed to light using a photolith mask so that an exposed pattern on the photoresist layer is physically altered in comparison to unexposed portions of the photoresist layer. The exposed portions of the photoresist layer generally correspond to portions of the substrate to be removed during a following step.

After the photoresist has been applied and exposed, an etching step is performed. In the etching step, unexposed portions of the photoresist are durable and resist etching. However, exposed portions of the photoresist are susceptible to etching and are removed during the etching step thereby exposing the underlying substrate layer. The layer of the substrate below the exposed photoresist portions is also susceptible to etching and is etched accordingly. Metal, dioxide, or polysilicon that was previously uniformly placed across the substrate is removed during this process. However, material left protected below the unexposed portions of the photoresist become portions of the various circuit elements across the substrate. Thus, a pattern in the substrate remains that coincides to the unexposed portions of the photoresist.

The etching step may be performed using either a wet etching technique or a dry etching technique. Using the wet etching technique, chemicals are applied to the substrate that removes the exposed portions of the photoresist and portions of the substrate underlying the photoresist. Using the dry etching technique, the substrate is bombarded



with particles that erode away the exposed portions of the photoresist and the underlying substrate.

5 The final step in the fabrication process is the stripping process wherein the remainder of the photoresist on the substrate is stripped from the substrate. Once the photoresist has been stripped, the four basic process steps are repeated until each layer on the substrate is complete. The four basis steps used in fabricating a semiconductor device or flat panel display are generally repeated a number of times until all circuit components have been fabricated. In a typical integrated circuit, at least three dielectric layers and at least three metal layers are fabricated on the substrate in addition to the transistors formed on the substrate itself.

10 With decreases in the size of components formed on substrates, dry etching processes have gained in popularity. Dry etching processes using a plasma are preferable over wet etching processes because of their anisotropic characteristics as compared to the isotropic characteristics of the wet etching process. In the plasma etching process, the substrate is bombarded with particles from a single direction, preferably normal to the surface of the semiconductor. In this fashion, plasma particles do not affect portions of the substrate protected by the unexposed photoresist. Wet etching processes, on the other hand, often destroy portions of the substrate that underlie the unexposed portions of the photoresist since the chemicals used in wet etching may invade the substrate laterally underneath the photoresist. Thus, in the fabrication of smaller circuit elements, wet etching may destroy some of the elements.

20 Further, with the advent of smaller and smaller circuits on substrates, the requirements of the etching step have become more difficult to attain. The dimensions of system components on modern substrates have become so small that a variation in strength of a plasma across the surface of the substrate may cause the plasma to properly etch the substrate in one location but destroy substrate components in another location. This type of destruction is often referred to as plasma damage or charge damage. In the case of a thin film oxide layer at the gates of transistors, the thin film is oftentimes only approximately 10 molecules thick. Thus, if plasma etching is improperly performed,

plasma will destroy the oxide layer, thus rendering the particular transistor non-operational.

FIG. 1 refers to a prior art plasma generation structure for generating a plasma within a process chamber. The plasma generation structure 10 may either be disposed on top of or within a process chamber 12. The plasma generation structure 10 includes a coil conductor 14 and a current source 16 driving an alternating current through the coil conductor 14. Typically, the current source 16 generates a current within the coil conductor 14 at a frequency of 13.56 Mhz, a frequency allotted to such applications. When alternating current is applied to the coil conductor 14 via the current source 16, an alternating magnetic field is generated within the process chamber 12. Within the process chamber 12, a vacuum is created and a process gas such as fluorine or chlorine is injected into the process chamber 12. The alternating magnetic field generated within the process chamber 12 excites the process gas within the process chamber 12 to a plasma state. The plasma generated within the process chamber then surface etches a substrate contained within the process chamber 12.

FIG. 2 illustrates another prior art plasma generation system 20 that includes a coil conductor 22 extending around an external portion of the process chamber 12. Current source 24 generates an alternating current in the coil 22 which, in turn, generates an alternating magnetic field within the process chamber 12. The alternating magnetic field extends into the process chamber 12 and excites a process gas within the process chamber 12 to produce a surface treating plasma.

In accordance with Maxwell's equations, the alternating magnetic fields created by the structures of FIG. 1 and FIG. 2 encircle the respective coil conductors 14 and 22 and have time varying intensities within the process chamber 12 based upon the structure of the coil conductors 14 and 22 and the applied current. As one skilled in the art will readily appreciate, the varying strength of the alternating magnetic field within the process chamber produces plasma of varying intensities across the process chamber 12, the intensity directly related to magnetic field strength. The structure 10 of FIG. 1 produces plasma having an intensity greater at the center of the process chamber 12 than at the edges of the process chamber 12. Alternatively, the structure 20 of FIG. 2 produces

plasma having an intensity lesser at the center portion of the process chamber 12 and greater near the walls of the process chamber 12.

5 The varying intensity of the plasma across the process chamber 12 causes uneven etching rates of substrates treated in the chambers 12. Uneven etching rates of substrates will cause a correct etching on some portions of the substrate and excessive or incomplete etching on other portions of the substrate, either destroying components on the substrates or incorrectly forming components on the substrate. Thus, the structures of FIG. 1 and FIG. 2 result in reduced process yields due to improper plasma applications.

10 Another limitation to the structures of FIG. 1 and FIG. 2 relates to the far reaching alternating magnetic fields created by the coils 14 and 22. As is known, the coil structures of FIG. 1 and FIG. 2 generate alternating magnetic fields that extend throughout the process chamber 12, through the process chamber walls, through the surrounding environment, and back into the process chamber 12. Substantial portions of these alternating magnetic fields extend to the surface of the substrate where they are bisected  
15 by conductive circuits on the substrate. Through bisecting the magnetic fields, voltages are induced which cause current to flow in the conductive circuits. Because the conductive circuits are typically constructed with small cross-sectional areas, the conductive circuits may be destroyed by the induced currents. However, even if the conductive circuits are not melted, the significant voltages induced by the magnetic coupling may destroy gate  
20 oxide layers. Thus, by their very structural nature, the structures of FIG. 1 and FIG. 2 destroy circuit components on substrates because of the far reaching alternating magnetic fields.

25 Since the alternating magnetic fields created by the coils 14 and 22 of FIG. 1 and FIG. 2 extend beyond the boundaries of the process chamber 12, the alternating magnetic fields affect the operation of other components surrounding the process chamber. Sensitive circuitry must be employed in conjunction with the semiconductor manufacturing to monitor the contents and environment within the process chamber 12. A particular example of such a sensor is a pressure sensor which monitors the pressure within the process chamber 12. Typical pressure sensors are greatly affected by the alternating  
30 magnetic fields generated by the structures of FIG. 1 and FIG. 2. Thus, the structures of

FIG. 1 and FIG. 2 oftentimes render sensors located near the process chamber 12 inoperable.

The structures of FIG. 1 and FIG. 2 form a magnetic circuit that extends beyond the boundaries of the process chamber 12. Thus, variations in the environment surrounding the process chamber 12 alters the magnetic circuit and therefore alter the magnetic field strength, including the strength of the magnetic fields produced within the process chamber 12. Resultantly, localized plasma intensity across the process chamber 12 alters producing inconsistent results.

One prior solution implemented to equalize the plasma distribution within the process chamber 12 of the structures of FIG. 1 and FIG. 2 was the installation of a silicon liner on the wall or top surface of the inside of the process chamber 12 to consume reactive species. By selectively consuming reactive species, the silicon liner altered the plasma intensity within the process chamber 12 to compensate for nonuniform plasma generation characteristics. With the structure of FIG. 1, a silicon liner was placed on an upper surface of the process chamber 12 and consumed reactive species at middle portion of the process chamber 12 where the plasma was generated most intensely. Alternatively, with the structure of FIG. 2, silicon liners were placed on the internal side walls of the process chamber 12 to consume reactive species bombarding the walls. Since the plasma was strongest near the walls, the consumption of reactive species near the walls helped to reduce plasma intensity near the walls of the process chamber 12.

However, the silicon liners used to equalize plasma were readily consumed by the reactive species. The cost of replacing the silicon liners was great and the replacement of the liners caused nonproductive down-time in the fabrication process. Thus, the silicon liners failed to provide a satisfactory solution to the problem.

Thus, there is a need in the art for an apparatus and method that will generate a uniform, neutral, and quiescent surface treating plasma or particle stream within a process chamber.

#### Brief Description of the Drawings

FIG. 1 is a diagrammatic view illustrating a prior art plasma generating structure;

FIG. 2 is a diagrammatic view illustrating another prior art plasma generating structure;

FIG. 3 is a diagrammatic view of an apparatus for generating a surface treating plasma within a process chamber in accordance with the present invention;

5       FIG. 4a is a diagrammatic top view of a coil layer illustrating an operation of the plurality of effective coils of a coil layer in accordance with the present invention;

FIG. 4b is a diagrammatic sectional side view of the coil layer of FIG. 4a illustrating current flows and magnetic field orientations in proximate to the effective coils;

10       FIG. 4c is a diagrammatic sectional side view of the coil layer of FIG. 4a illustrating various coil element structures in accordance with the present invention;

FIG. 4d is a diagrammatic sectional side view of the coil layer of FIG. 4a illustrating various coil element structures that provide a process gas to the process chamber in accordance with the present invention;

15       FIG. 4e is a diagrammatic sectional side view of the coil layer of FIG. 4a illustrating various coil element structures that include cooling passages and provide a process gas to the process chamber in accordance with the present invention;

FIG. 4f is a diagrammatic top view of a coil layer illustrating an alternative effective coil structure wherein each effective coil has a substantially triangular shape in accordance with the present invention;

20       FIG. 5a is a diagrammatic top view illustrating an effective coil structure of a coil layer and related drive element connections in accordance with the present invention;

FIG. 5b is a diagrammatic top view illustrating an alternative effective coil structure of a coil layer and related drive element connections in accordance with the present invention;

25       FIG. 5c is a diagrammatic top view illustrating an alternative effective coil structure of a coil layer and related drive element connections in accordance with the present invention;

30       FIG. 5d is a diagrammatic top view illustrating the effective coil structure of FIG. 5c including mirror image coil elements laid upon a first coil layer in accordance with the present invention;

FIG. 6a is a diagrammatic top view illustrating an alternative effective coil structure of a coil layer in accordance with the present invention;

FIG. 6b is a diagrammatic top view illustrating an alternative effective coil structure of a coil layer in accordance with the present invention;

5 FIG. 6c is a diagrammatic top view illustrating an alternative effective coil structure of a coil layer in accordance with the present invention;

FIG. 6d is a diagrammatic top view illustrating an alternative effective coil structure of a coil layer in accordance with the present invention;

10 FIG. 6e is a diagrammatic top view illustrating an alternative effective coil structure of a coil layer in accordance with the present invention;

FIG. 6f is a diagrammatic perspective view illustrating a termination and shield structure for use with the coil layer structures of the present invention;

FIG. 6g is a diagrammatic perspective view illustrating a termination and shield structure for use with the coil layer structures of the present invention;

15 FIG. 6h is a diagrammatic perspective view illustrating a termination and shield structure for use with the coil layer structures of the present invention;

FIG. 6i is a diagrammatic perspective view illustrating a termination and shield structure for use with the coil layer structures of the present invention;

20 FIG. 6j is a diagrammatic perspective view illustrating a termination and shield structure for use with the coil layer structures of the present invention;

FIG. 6k is a diagrammatic perspective view illustrating a drive element layer structure for driving the coil layer structures of the present invention;

FIG. 6l is a diagrammatic perspective view illustrating an alternative drive element layer structure for driving the coil layer structures of the present invention;

25 FIG. 6m is a diagrammatic perspective view illustrating an alternative drive element layer structure for driving the coil layer structures of the present invention;

FIG. 7a is a diagrammatic perspective view illustrating a shielding structure for shielding the coil elements of the present invention;

30 FIG. 7b is a diagrammatic perspective view illustrating an alternative shielding structure for shielding the coil elements of the present invention;

FIG. 8a is a schematic diagram illustrating a structure for connecting a coil layer to a drive element in accordance with the present invention;

FIG. 8b is a schematic diagram illustrating an alternative structure for connecting a coil layer to a drive element in accordance with the present invention;

5        FIG. 8c is a signal timing diagram illustrating alternating effective closed loop currents, alternating magnetic fields, and biasing voltages in accordance with the present invention;

FIG. 9a is a diagrammatic top view illustrating an alternative coil layer structure in accordance with the present invention;

10        FIG. 9b is a diagrammatic view in perspective illustrating a particular construction of the coil layer structure of FIG. 9a;

FIG. 9c is a diagrammatic view in perspective illustrating an alternative construction of the coil layer structure of FIG. 9a;

15        FIG. 10 is a diagrammatic view in perspective of an alternative coil layer structure wherein coil elements comprise flat conductors in accordance with the present invention;

FIG. 11 is a diagrammatic side view illustrating an alternative apparatus for generating a surface treating plasma within a process chamber in accordance with the present invention wherein a coil layer associated with the apparatus resides outside of the process chamber;

20        FIG. 12 is a diagrammatic side view illustrating an alternative apparatus for generating surface treating plasma within a process chamber in accordance with the present invention wherein a dome shaped coil layer surrounds a top and a portion of the sides of a process chamber;

25        FIG. 13 is a diagrammatic side view illustrating an apparatus for producing a uniform and directional (anisotropic) surface treating plasma within a process chamber in accordance with the present invention including a plasma generating coil layer, plasma filter, and accelerator grid;

FIG. 14 is a diagrammatic side view illustrating an apparatus for directing plasma away from an inner surface of a process chamber in accordance with the present invention;

FIG. 15 is a diagrammatic side view illustrating an apparatus for producing a uniform and quiescent surface treating plasma within a process chamber in accordance with the present invention;

5 FIG. 16 is a diagrammatic side view illustrating an apparatus for generating a uniform and directional (anisotropic) surface treating plasma in accordance with the present invention including a plasma generating coil layer, a first filtering coil layer, and a conductive grid;

FIG. 17 is a diagrammatic side view illustrating a plasma filtering and accelerating apparatus in accordance with the present invention;

10 FIG. 18a is a diagrammatic side view illustrating a plasma generation, filtering, accelerating, and neutralizing apparatus in accordance with the present invention;

FIG. 18b is a signal timing diagram illustrating the application of biasing signals to the apparatus of FIG. 18a in order to cause the filtering, acceleration, and neutralizing recombination of plasma particles;

15 FIG. 18c is a signal timing diagram illustrating an alternative mode of biasing signals to the apparatus of FIG. 18a in order to cause the filtering, acceleration, and neutralizing recombination of plasma particles;

FIG. 19 is a diagrammatic side view illustrating a combination plasma filtering and neutralizing apparatus in accordance with the present invention;

20 FIG. 20 is a diagrammatic side view illustrating a particular coil layer structure in accordance with the present invention;

FIG. 21 is a logic diagram illustrating a method for generating a uniform and quiescent surface treating plasma in accordance with the present invention;

25 FIG. 22 is a logic diagram illustrating a method for filtering a noisy plasma to allow a uniform a neutralized plasma to surface treat a substrate;

FIG. 23 is a logic diagram illustrating a combined method for generating, filtering, neutralizing, and charge filtering a surface treating plasma in accordance with the present invention;

30 FIG. 24 is a diagrammatic perspective view of a coil layer structure for operation at high frequencies in accordance with the present invention;



FIG. 25 is a diagrammatic perspective view of an alternative coil layer structure for operation at high frequencies in accordance with the present invention;

FIG. 26 is a diagrammatic perspective view of another alternative coil layer structure for operation at high frequencies in accordance with the present invention;

5        FIG. 27 is a diagrammatic perspective view of still another alternative coil layer structure for operation at high frequencies in accordance with the present invention;

FIG. 28 is a diagrammatic perspective view of a further alternative coil layer structure for operation at high frequencies in accordance with the present invention; and

10        FIG. 29 is a diagrammatic perspective view of an additional coil layer structure for operation at high frequencies in accordance with the present invention;

#### Detailed Description of the Drawings

The present invention relates to various apparatus and methods for generating, filtering, and neutralizing a surface treating plasma within a process chamber to allow a  
15        uniform, filtered, neutralized, and/or quiescent plasma to surface treat a substrate within a process chamber. Preferably, the apparatus includes, in various embodiments, a coil layer having a plurality of operably connected coil elements connected to form a plurality of effective coils. The plurality of effective coils are adjacently spaced apart to form the coil layer. A drive element may be coupled to the plurality of operably connected coil  
20        elements to induce effective closed loop currents in each of the plurality of effective coils. The effective closed loop currents in each of the plurality of effective coils generates a magnetic field in accordance with Maxwell's equations. The magnetic fields induced at the effective coils may be configured and operated to generate a plasma, to filter a plasma, to neutralize a plasma, or to confine plasma away from hardware. The apparatus of the  
25        present invention may be used in conjunction with additional elements to accelerate a plasma within a process chamber.

Resultantly, the apparatus and method of the present invention creates a uniform filtered, neutralized, and/or quiescent plasma for the surface treating of a substrate within a process chamber. The plasma has a uniform strength across the surface of the substrate  
30        being treated to enhance uniform processes and eliminate plasma damage across the

substrate. Because of the uniform process and reduction in plasma damage, process yields increase. Further, due to the construction of the apparatus, plasma generation may be easily initiated and maintained.

5 The coil layer structure of the present invention does not induce magnetic fields that extend to the substrate surface. Resultantly, little or no inductive coupling of current onto the substrate surface occurs and little or no damage results due to the EMF coupling effects. Further, because the magnetic fields created at the effective coils typically do not extend beyond the confines of the process chamber, external instruments are not affected and changes external to the process chamber do not affect the generation of plasma within  
10 the process chamber itself.

Thus, the apparatus and method of the present invention provides a complete system for generating a uniform filtered, neutralized, and/or quiescent surface treating plasma for treating a substrate within the process chamber. In accordance with the present invention, the plasma may be selectively generated, filtered, neutralized, and/or accelerated  
15 toward the substrate for treatment in an easily maintainable, low cost, and high throughput manufacturing system.

FIG. 3 illustrates an apparatus 30 for generating a surface treating plasma 38 within a process chamber 36. The apparatus 30 preferably comprises a generation coil layer 32 having a plurality of operably connected coil elements wherein the plurality of operably  
20 connected elements form a plurality of effective coils. The plurality of effective coils are adjacently spaced apart to form the generation coil layer 32. The generation coil layer 32 may be disposed within the process chamber 36, outside of the process chamber 36, or both inside and outside of the process chamber 36 depending on the particular system requirements. Furthermore, the generation coil layer 32 may be of any layer shape such  
25 as, but not limited to, a substantially planar layer, a curved layer, a cylindrically shaped layer, a dome shaped layer, a spherical layer, or a hyperbolic layer. Multiple coil layers 32 may be joined to form a composite layer, may be joined with grids, and in various other constructions without departing from the present invention.

A drive element 34 operably couples to the coil layer such that it electrically  
30 connects to each of the plurality of coil elements within the coil layer 32. The drive

element 34 generates an effective closed loop current in each of the plurality of effective coils of the coil layer 32 so as to induce a magnetic field at each of a plurality of effective coils. The magnetic fields induced at the plurality of effective coils of the generation coil layer 32 generate the surface treating plasma 38 within the process chamber 36.

5       The surface treating plasma 38 treats a substrate 40 that is held in place by a chuck 42. The surface treating plasma 38 generated in accordance with the present invention therefore performs a plasma etching, ashing, diffusion, surface cleaning, or other treating process on the substrate 40. Because of the construction of the generation coil layer 32, the surface treating plasma 38 is uniformly generated across the process chamber 36 and  
10       therefore uniformly treats the substrate 40.

      Depending upon the construction of the coil layer 32, plasma 38 may be generated such that it surrounds the coil layer 32. However, in some constructions, the coil layer 32 may be disposed within the process chamber 36 such that plasma 38 is generated only on a single side of the coil layer 32. Preferably, the construction of the coil layer 32 will  
15       be had based upon the particular application.

      The drive element 34 may comprise an alternating source, a direct source, or a combination of both an alternating and direct source (combinational source) depending upon the particular application. Preferably, the drive element 34 comprises an alternating current or voltage source operating at a frequency of 13.56 MHz, a frequency that has  
20       been assigned to this particular type of application. In this fashion, the effective closed loop currents induced at the plurality of effective coils oscillate at a frequency of 13.56 Mhz. Thus, the magnetic fields created at the effective coils alternate at 13.56 MHz, generating plasma 38 within the process chamber 36 at the same frequency. However, the drive element 34 could also comprise a direct source or combinational source having both  
25       direct and alternating characteristics so that it can produce a pulsed signal or a time modulated signal that may be required depending upon particular system requirements and specifications and may include additional circuit elements to adjust the operation of the filter layer 32. Depending upon the particular embodiment of the coil layer 32 and the application, the frequencies of operation of the drive element 34 may vary from the

preferred frequency and extend from the low radio frequency range, past the ultra high frequency range, and into the microwave range.

The current magnitude required to generate a plasma 38 within the process chamber 36 depends upon the environmental characteristics within the process chamber 36 as well as the construction of the coil layer 32. The strength of a magnetic field generated at the effective coils is proportional to the effective closed loop current magnitude, proportional to the number of effective loops at the effective coil, and inversely proportional to an effective diameter of the effective coil elements. Thus, a given current magnitude will produce a higher intensity magnetic field in an effective coil having a smaller effective diameter than in an effective coil having a larger effective diameter. When each of the effective coils is approximately 1 centimeter in diameter and of a single effective closed loop, the current magnitude required to generate the surface treating plasma 38 within the process chamber 36 is approximately 1 ampere at a typical vacuum pressure used in the process. The magnitude of the effective closed loop current is varied depending upon the construction of the coil layer 32, the environmental characteristics within the process chamber 36, and the desired plasma 38 density that is required for the particular process within the process chamber 36.

FIGs. 4a and 4b respectively illustrate a top view and a sectional side view of the orientation of the coil elements 46 within the coil layer 32, the effective closed loop current 48 flowing through each effective coil 47, and the magnetic fields 50 and 52 induced by the effective closed loop current 48. The coil layer 32 is essentially comprised of the plurality of operably connected coil elements 46 that are connected so as to form the plurality of effective coils 47. Thus, each of the plurality of effective coils 47 has an effective closed loop conductive path that surrounds a central portion of the effective coil 47. The effective coils 47 are adjacently spaced apart to form the coil layer 32. The plurality of effective coils 47 could comprise separately disposed and discrete complete coils or could be constructed in a more efficient manner as will be further described herein. The effective coils 47 could include additional magnetic material, such as a ferrite, placed within all or a portion of the effective coils 47 to increase magnetic field 50 and 52 intensity at the effective coils 47.

With the drive element 34 operably coupled to each of the plurality of coil elements 46, an effective closed loop current 48 is generated in each of a plurality of effective coils 47. Resultantly, magnetic fields 50 and 52 are generated at each of the plurality of effective coils 47. As previously discussed, magnetic fields 50 and 52 are dependent upon the effective closed loop current 48 created by the drive element 34 according to Maxwell's equations. Magnetic fields 50 generated at the plurality of effective coils 47 are illustrated to extend from a surface of the FIG. 4a while magnetic fields 52 are illustrated to extend into the surface of the paper. Magnetic fields 50 and 52 of adjacent effective coils 47 are complementary, and thus differing in polarity. Resultantly, adjacent magnetic fields 50 and 52 effectively turn around to form a closed loop thereby minimizing the magnetic field extending from the coil layer 32. With minimum magnetic fields generated away from the coil layer 32, little or no damage is caused on the substrate surface due to EMF coupling. As opposed to the prior art devices, the magnetic field generated by the coil layer 32 drops off significantly away from the coil layer. Thus, the apparatus of the present invention inductively couples significantly less energy to the substrate 40 than did the prior devices. Further, because plasma strength across the coil layer 32 is substantially uniform, localized damage on the substrate due to voltage differentials and current flows is reduced as compared to the prior devices.

FIG. 4b is a side view of the construction of the coil layer 32 of FIG. 4a. As shown, current traveling in adjacent coil elements 46 travels in opposite directions. In this fashion, the effective closed loop current 48 are generated so as to induce alternately oriented magnetic field 50 and 52 at adjacent effective coils 47. An actual closed loop current and the effective closed loop current 48 of the present invention generate equivalent magnetic fields 50 and 52 at the effective coils 47.

In accordance with the present invention, voltage differentials among the plurality of effective coils 47 may be induced so as to create electric fields among the plurality of effective coils 47. Furthermore, when the coil layer 32 is constructed of a plurality of sub-layers, each having effective coils 47, the sub-layers may be voltage biased with respect to one another to create electric fields between the sub-layers. The electric fields between the effective coils 47 may be used to align charged particles traveling within the

process chamber 36 or may be used to deflect charged particles, depending upon the application.

Even without creating electric fields amongst the plurality of effective coils 47, the magnetic fields created by the coil layer 32 cause charged particles to deflect or bounce  
5 away from the coil layer 32, thus causing the coil layer 32 to exhibit a filtering characteristic. The Lorentz force acts upon a charged particle moving within a magnetic field and cutting magnetic field lines. Charged particles moving within the magnetic field are deflected by the Lorentz force according to Maxwell's equations, the Lorentz force equal to the cross product of the charged particle's velocity and the magnetic field 50 or  
10 52. The Lorentz force therefore deflects high energy charged plasma particles from colliding with the plurality of coil elements 46.

As is known, the bombardment of a conductor, such as the one used to construct the coil elements 46, with high energy charged plasma particles generates heat and current in the conductors and can cause the conductors to produce particles which contaminate the  
15 process and degrade the conductors. The heat and current must be removed while contamination can destroy the process. Therefore, it is desirable to prevent the charged plasma particles from colliding with the coil elements 46. The magnetic and electric fields created in conjunction with the apparatus 30 of the present invention minimizes collision of charged plasma particle with the coil elements 46. Therefore, heat and current  
20 generation are reduced and a cleaner process will be achieved by the apparatus of the present invention. Further, replacement costs will be avoided.

The plurality of operably connected coil elements 46 may comprise a plurality of conductors disposed within the process chamber 36. Such a structure is illustrated in FIG. 3. However, as will be described more fully hereinafter, the plurality of operably  
25 connected coil elements 46 may comprise a plurality of conductors disposed outside of the process chamber. In either case, in order to create the effective closed loop currents 48, the coil elements 46 must comprise a material that will conduct current. Preferably, the coil elements 46 are formed of metal or carbon as the conductor. However, differing material could be employed to enable the operation of the coil layer 32 in accordance with  
30 the present invention.

A coating may be disposed on the operably coupled coil elements 46 that prevents chemical reactions between the coil elements 46 and the plasma gases. The coating is preferably formed of a durable material that seals the coil elements 46 to prevent the infusion of plasma particles into the coil elements 46. The coating allows for expanded selection of process gases as well as extending the range of plasma density generated by the coil layer 32.

FIG. 4c illustrates various cross-sectional shapes of conductor elements 46 of the present invention. Cross-sectional shapes illustrated include square, rectangular, oval, oblong, flat, teardrop, and round shapes. Each shape serves particular goals related to the installation. For example, the teardrop shape illustrated has a sharp surface at an upper portion of the coil layer 32. In this fashion, its effective cross-sectional capture area for particles traveling toward the coil layer 32 is reduced. Thus, a coil layer 32 including the teardrop shaped conductor collects less charge than coil layers 32 having different cross-sectional shapes.

For the purposes of altering plasma ion flow within the process chamber 36, the coil layer 32 may be oriented at a non-perpendicular angle with respect to the substrate 40. Of course, when coil layers 32 are stacked upon one another, the conductor of adjacent coil layers 32 may have differing shapes. Further, even within a single coil layer 32, conductors within the coil layer 32 may have different shapes across the coil layer 32 to generate a particular plasma pattern.

FIG. 4d illustrates constructions of coil elements 46 wherein the coil elements 46a through 46f each have the ability to supply gas within the process chamber 36. A process gas, such as chlorine, fluorine, oxygen, hydrogen, argon, helium, carbon containing gas, silicon containing gas, arsenic containing gas, germanium containing gas, metal element containing gas, any combination of these, or another process gas may be introduced into the process chamber via coil elements 46a-46f which have hollowed centers. As illustrated in FIG. 4d, the coil elements 46a through 46f also have openings through which the process gas enters the process chamber 36. These openings are located on the coil elements so that they directionally release process gas. For example, assuming that the substrate 40 resides below the coil layer 32 of FIG. 4d, coil element 46a releases process

gas into the process chamber 36 toward the substrate 40. Alternatively, coil elements 46b and 46d release process gas into the process chamber away from the substrate 40 so that the process gas resides within the process chamber 36 for a relatively longer period of time before treating the substrate 40. Depending upon the particular application, process gas  
5 may be injected directionally in a variety of ways with the structures illustrated in FIG. 4d.

The conductive pipes receive the process gas externally and move the process gas into the process chamber 36. The conductive pipes may also circulate a coolant within the process chamber when constructed in a dual pipe configuration. The process gas provided  
10 through the conductive pipes may be circulated as well to remove by-products from the process chamber generated during the plasma etching process.

The coil elements 46 of FIG. 4e are constructed so that they may also provide process gas to the process chamber 36. However, the coil elements 46 not only include a structure for circulating a coolant but also include a structure for providing process gas  
15 to the process chamber 36 much like the structure illustrated in FIG. 4d. Thus, the construction may be employed in a very high power plasma generation or in a low temperature application. Coil elements 46a through 46f are constructed of conductive pipes that circulate a coolant. The conductive pipes extend through a wall of a process chamber to circulate the coolant into and out of the process chamber 36. The coolant is  
20 preferably cooled externally in a chiller, and circulated again through the conductive pipes. The circulating coolant reduces the temperature of the plurality of operably connected coil elements 46 of the coil layer to increase the efficiency of operation of the coil layer 32 during high power operation. The reduction in temperature of the operably connected coil elements 46 extends the life of the coil elements 46 as well as extending the possible  
25 applications of the present invention to the special process requirements of high power an/or low temperature processes. The circulating coolant may be contained within a tubing system separately located within the coil elements 46 such that the tubing system does not share walls with the coil elements 46. Such a structure is shown at elements 46a, 46e, and 46f. Alternatively, the tubing system in which the circulating coolant flows  
30 may share a wall with the coil elements 46 as is shown as elements 46b, 46c, and 46d.



FIG. 4f illustrates a particular construction 950 of the coil elements 46 and a resulting coil layer 32 in accordance with the present invention. In this embodiment, the plurality of operably connected coil elements 46 comprise a first plurality of substantially parallel conductors 952, a second plurality of substantially parallel conductors 954, and a third plurality of substantially parallel conductors 956. In this construction, each of the effective coils 47 is formed by a portion of one of the first plurality of substantially parallel conductors 952, a portion of one of the second plurality of substantially parallel conductors 954, and a portion of one of the third plurality of substantially parallel conductors 956. As illustrated, adjacent effective coils 47 share conductor segments.

The first plurality of substantially parallel conductors 952 conducts current in a first direction. The second plurality of substantially parallel conductors 954 is disposed angularly with respect to the first plurality of substantially parallel conductors 952 and conducting current in a second direction. The third plurality of substantially parallel conductors 956 is disposed angularly with respect to both the first plurality of substantially parallel conductors 952 and the second plurality of substantially parallel conductors 954. Further, the third plurality of substantially parallel conductors 956 conducts current in a third direction. Resultantly, the three sets of conductors 952, 954, and 956, each conducting a current in a differing direction, create the effective closed loop current 48 at each of the effective coils 47. Preferably, the conductors 952, 954, and 956 form the plurality of effective coils 47 wherein each of the plurality of effective coils 47 has a substantially triangular shape.

The sets of conductors 952, 954, and 956 may be easily connected to a single source to generate the current pattern illustrated. Because each conductor of all of the conductors has a relatively short length, and because the conductors would effectively be in parallel, voltage drop along the conductors will be minimal as will voltage differentials. Thus, the structure 950 of FIG. 4f provides the significant benefits of simple construction, efficient operation, and effective operation.

FIG. 5a illustrates a diagrammatic construction of the operably connected coil elements 46 of FIGs. 4a and 4b. As shown, the plurality of operably connected coil elements comprise a plurality of substantially parallel conductors 54. Each of the plurality

of substantially parallel conductors 54 comprises a plurality of segments 55. Substantially parallel segments 55 of adjacent substantially parallel conductors 54 form the plurality of effective coils 47. The substantially parallel conductors 54 are terminated at terminations 56 to cause the current flowing in the substantially parallel conductors 54 to flow in opposite directions in adjacent conductors 54. In this fashion, when a drive element 34 is connected to the plurality of substantially parallel conductors 54, the current flowing through the substantially parallel conductors 54 causes the effective closed loop current 48 of FIGs. 4a and 4b to flow at each of the effective coils 47. The effective closed loop currents 48 at the effective coils 47 cause the magnetic fields 50 and 52 to be created that will be used to create the plasma 38 within the process chamber 36.

As illustrated in FIG. 5a, each of the plurality of segments 55 is substantially perpendicularly oriented. In this fashion, each of the effective coils 47 comprises a rectangular shape. Further, as illustrated in FIG. 5a, adjacent effective coils 47 form a pattern of rectangles across the coil layer 32 in a grid fashion. The drive element 34 providing a current or voltage to the coil layer 32 must be connected to the parallel conductors 54 to cause current in adjacent conductors to travel in substantially opposite directions. However, if the coil layer 32 is used without a current or voltage source, such as would be the case in some filtering applications, the parallel conductors would be terminated to allow the current in adjacent conductors 54 to flow in substantially opposite directions.

Furthermore, an impedance matching network may be used between the drive element 34 and the coil layer 32 to impedance match the drive element to the load. In this fashion, reflections will be reduced to make it is easier to control the magnetic fields generated by the coil layer 32. Because impedance matching networks are known, they will not be further described herein except to expand on the teachings of the present invention.

The coil layer 32 diagrammatically illustrated in FIGs. 4a and 4b explains the basic concepts of current polarity, magnetic field polarity, and magnetic field attenuation among the adjacent effective coils 47 of the present invention. However, the teachings of the present invention are not limited to the particular structures illustrated. The teachings of

the present invention may be readily practiced in various manners not limited by the illustrations provided herein.

FIG. 5b illustrates an alternative construction of the coil layer 32 wherein each of the plurality of segments 55 is substantially circular in shape. The substantially circular segments 55 each carry a current traveling through the substantially perpendicular conductors 54 from a first portion of the coil layer 32 to a second portion of the coil layer 32. The substantially circular segments 55 of the substantially parallel conductors 54 form the effective coils 47. Thus, as illustrated, current traveling through the substantially parallel conductors 54 creates the effective closed loop current 48 of FIG. 4a in the effective coils 47.

Furthermore, as illustrated in FIG. 5b, the drive element 34 may be constructed in a fashion differing from that of FIG. 5a to produce currents having alternating directions in adjacent effective coils 47. In the connection of the drive element 34 to the substantially parallel conductors 54 of FIG. 5a, the path of current traveling through the conductors 54 is long and therefore the series resistance of the path can be large. Depending upon the resistance of the segments of the conductors 54, the total series resistance of the path may be great. In the connection of the drive element 34 to the coil layer 32 of FIG. 5b, alternating substantially parallel conductors 54 connect to a first side of the drive element 34 while the other alternating substantially parallel conductor 54 couple to a second side of the drive element 34. Thus, in the connection of FIG. 5b, the drive element 34 drives the conductors 54 in parallel.

Thus, the drive element 34 of FIG. 5a will likely see a larger series impedance as compared to the drive element 34 of FIG. 5b. However, current flowing in each of the substantially parallel conductors 54 of FIG. 5a is substantially equal thus providing the benefit of an equal closed loop current 48 and magnetic field strength at each of the effective coils 47. With the structure of FIG. 5b, there may be variations in the impedances of the substantially parallel conductors 54 such that additional lumped circuit elements 72 are added into the circuit to equalize the currents passing through the substantially parallel conductors 54. For example, at the connection points to the drive

element, one of the conductors 54 may include a lumped circuit element 72 such as an inductor, capacitor, or resistor to equalize the current within that particular conductor 54.

It may be advantageous in some situations to have a larger current passing through one portion of the coil layer 32 than in other portions of the coil layer 32. Such variations may be performed with the structure of FIG. 5b by varying lumped circuit element 72 values. In this fashion, the engineers monitoring the process may tune the coil layer 32 to produce a more uniform plasma within the process chamber. The connection configuration used to connect the coil layer 32 to the drive element 34 shown in FIG. 5a may be used with the coil layer 32 of FIG. 5b and vice versa. The connections illustrated in FIGs. 5a and 5b may be used with any other coil layer 32 in accordance with the present invention.

The drive element 34 used in a particular application is selected based upon the desired magnetic fields to be generated by the coil layer 32. As previously described, the drive element may comprise an AC source, a DC source, or a combination of both. The drive element 34 may also comprise a combination of either an unpulsed voltage or current source or a pulsed voltage or current source to create particular wave form in the coil layer 32. For example, a DC current and AC current may be superimposed to create a current passing through the plurality of parallel conductors 54 of FIG. 5b. Further, the parallel conductors 54 may be biased with a DC voltage or a pulsed DC voltage to elicit certain behaviors within the process chamber 36. For example, the complete coil layer 32 may be biased with respect to the plasma 38, either forcing the plasma away from or toward the coil layer 32, depending upon the biasing, to alter the velocity of plasma flowing toward the coil layer 32. The drive element 34 could also bias the coil layer 32 with respect to the process chamber, with respect to an accelerator grid also contained within the process chamber, with respect to a filter contained in the process chamber, or with respect to the chuck which holds the substrate to cause plasma distribution within the chamber to alter the flow of plasma within the process chamber as well.

FIG. 5c illustrates an alternative construction of the coil layer 32 in accordance with the present invention. As shown, a plurality of substantially parallel conductors 54 extend from a first portion of the coil layer 32 to a second portion of the coil layer 32.

Segments of the substantially parallel conductors 54 orient substantially perpendicularly to one another to form the boundaries of the effective coils 47. For example, one parallel conductor 54 forms three quarters of a path around a particular effective coil 47 while an adjacent parallel conductor 54 forms the remainder of the path around the effective coil 47. Current source 62 provides the current through the parallel conductors 54 for generating the magnetic field. Voltage sources 60 preferably bias adjacent substantially parallel conductors 54 to create an electric field between the conductors 54.

The edges of the adjacent substantially parallel conductors 54 pass close enough to one another to avoid edge effects in the creation of the magnetic fields 50 and 52 but not so close as to break down the dielectric between the adjacent conductors 54. In the coil layer 32, dielectric may be selectively applied between the adjacent substantially parallel conductors 54 to avoid an arcing between the conductors 54. However, the voltage between adjacent substantially parallel conductors 54 is generally small when the conductors 54 have low impedance.

The voltage between adjacent substantially parallel conductors 54 may be biased using voltage sources 60. In this fashion, electric fields between the adjacent parallel conductors 54 aid in generating or filtering the plasma. In this situation, additional insulation may be required between adjacent conductors 54. The insulation of conductors using coatings, anodization, or insulating liners is known and will not be more fully described hereinafter.

Preferably, at least a portion of the plurality of substantially parallel conductors 54 further comprise at least one looped segment 64. Each looped segment 64 forms a closed loop at one of the effective coils 47 to enhance the creation of the magnetic fields at the particular effective coils 47. As illustrated, three sides of each of the effective coils 47 associated with looped segment 64 have a double current flow. Adjacent substantially parallel looped segments 64 may be constructed to create a double current flow at each of the segments 55 or legs of the particular effective coils. In this fashion, enhanced magnetic field generation may be realized by simply looping substantially parallel conductors 54 back upon themselves across the coil layer 32.

As illustrated in FIG. 5d, a mirrored image conductor 54A may be laid atop the substantially parallel conductors 54 to increase the number of loops at each effective coil 47. By having each effective coil 47 contain multiple loops, in a multiple coil layer fashion, the effective magnetic field strength at each effective coil 47 increases based upon the additional coils. Further, the construction of FIG. 5d reduces corner effects that would be had with a single layer of conductors.

Thus, magnetic field intensity may be varied both with drive element control and with the construction and orientation of the effective coils 47 of the coil layer 32. In this fashion, the present invention enables great control in the generation of plasma within the process chamber.

FIG. 6a illustrates an effective coil structure 800 of a coil layer 32 that may be implemented in accordance with the present invention. Each of a plurality of operably connected coil elements 46 comprises a plurality of conductor segment 802. The conductor segments 802 are configured such that each effective coil 47 is formed by four conductor segments 802. As shown, each conductor segment 802 includes a first end 804 and a second end 806 referenced such that current enters the first end 804 and exits the second end 806. Of course, the references applied are for illustration purposes only. The conductor segments 802 are substantially straight so that the effective coils 47 have a square shape. As shown, the conductor segments 802 operate to produce the effective closed loop current at the effective coils 47 to generate the magnetic fields 50 and 52.

Because of the relatively short lengths of the conductor segments 802 ohmic heating is minimized. Further, heat generated within the conductor segments 802 have a short length to flow to a heat sink. Thus, reduced heat generation and increased heat sink ability result in a cooler operation of the structure 800.

Since each conductor segment 802 may be uniquely accessed, its impedance may be may be finely tuned to achieve a desired current level. With the current level in each conductor segment 802 finely tuned, the magnetic field intensity and resultantly the plasma level within the process chamber 36 may also be finely tuned. As has been previously discussed, the benefits of a uniform plasma within the process chamber 36 results in higher

yields and reduced damages. Thus, the ability to finely tune the plasma distribution via tuning the conductor segments 802 provide significant benefits.

Further, because the conductor segments 802 have a low series impedance due to their relatively short lengths, voltage drop along the length of the segments 802 is minimized. Thus, the voltage across each of the conductors segments may be held substantially uniform across the coil layer 32, and the overall voltage of the coil layer may be controlled. By controlling the voltage of the coil layer 32, capacitive coupling between the coil layer and the plasma within the process chamber is reduced. A reduction in the capacitive coupling between the coil layer 32 and the plasma allows a more uniform plasma to be generated within the process chamber, reduces plasma dissipation into the conductor segments 802, and resultantly reduces heating within the process chamber 36 and increases the efficiency of the coil layer 32.

FIG. 6b illustrates an effective coil structure 810 of a coil layer 32 in accordance with the present invention that may be used with the apparatus of FIG. 3. The structure 810 includes a plurality of conductor segments 812 that form the plurality of operably connected coil elements 46. Each effective coil 47 is formed by at least one conductor segment. Preferably, in accordance with the structure 810 of FIG. 6b, two conductor segments 812 form each effective coil 47. Each conductor segment 812 includes a first end 814 and a second end 816. Preferably, current is injected into the first end 814 and sunk at the second end 816. Thus, the structure 810 of FIG. 6b provides benefits similar to those of the structure 800 of FIG. 6a. However, the structure 810 of FIG. 6b uses slightly longer conductor segments 812 and resultantly has a reduced construction cost.

FIG. 6c illustrates an effective coil structure 820 of a coil layer 32 in accordance with the present invention that may be used with the apparatus of FIG. 3. The structure 820 includes a plurality of conductor segments 822, each having a first end 824 and a second end 826. As is shown, the plurality of conductor segments 824 are arranged so as to produce the plurality of effective coils 47. As with prior embodiments, at each effective coil 47, a magnetic field 50 or 52 is generated.

In accordance with the structure of FIG. 6c, the effective coils 47 are formed either by two conductor segments 822 or by more than two conductor segments 822, depending

upon the particular effective coil 47. In either case, the structure 820 of FIG. 6c provides the important benefits of reduced conductor length with resultant heat generation reduction and cooling benefits previously described.

FIG. 6d illustrates an effective coil structure 830 having a plurality of conductor segments 832 forming the effective coils 47. Each of the conductor segments 832 includes a first end 834 into which current is injected and a second end 836 from which current is removed. In accordance with the structure 830 of FIG. 6d, each conductor segment 832 substantially surrounds one of the effective coils 47. However, some of the effective coils are surrounded by portions of more than one conductor segment 832. The structure 830 of FIG. 6d provides the benefits resulting from shorter conductor segment 832 lengths. These benefits have previously been discussed and are not discussed with reference to FIG. 6d.

FIG. 6e illustrates an effective coil structure 840 similar to the structure of FIG. 6d. In the structure 840 of FIG. 6e, each operably connected coil element comprises a conductor segment 842. Each conductor segment 842 includes a first end 844 into which current is injected and a second end 846 from which current is removed. Each of the conductor segments 842 surrounds substantially one of the effective coils 47. However, as was the case with FIG. 6d, some of the effective coils 47 within the structure 840 are substantially surrounded by more than one of the coil segments 842. Thus, the structure 840 of FIG. 6e also provides benefits relating to reduced conductor length, these benefits previously have been discussed.

The structures of FIGs. 6a through 6e could be implemented with various other geometric shaped effective coils 47 as well. For example, conductor segments could form a plurality of triangularly shaped effective coils 47. Conductor segments could comprise one, two, or three legs of the triangularly shaped effective coils 47. Further, conductor segments could be disposed to create other various geometric shaped effective coils 47 as well. Particular geometric shapes of the effective coils 47 could provide benefits in particular situations not provided in other situations and vice versa. However, the principles of the present invention are applicable to geometric shapes not particularly disclosed in the present disclosure.



FIG. 6f illustrates a shielded connection structure 850 for operably connecting a drive element to the conductor segments of the structures of FIGs. 6a through 6e. The structure 850 includes preferably a dielectric coating formed on portions of conductor segments that prevents conduction between conductors. The structure 850 may be constructed as twisted insulated wires or as a singularly formed dielectric segment having passages through which wires pass. The structure 850 of FIG. 6f allows conductors injecting current and removing current from effective coil structures to pass in opposite directions without arcing between conductors.

FIG. 6g illustrates a termination and shield structure 860 wherein a triaxial cable is used to connect a source or termination to the effective coil structure, the structure 860 also for shielding portions of conductor segments of the structures of FIGs. 6a through 6e. The triaxial cable allows two connections to be made within a shielded portion of the triaxial cable. In this fashion, the connections providing or removing current from the effective coil structure may isolated from one another and shielded from the environment by the outer conductive portion of the triaxial cable. However, the outer conductive portion could also be used to conduct current if required.

FIG. 6h illustrates a termination and shield configuration 870 wherein a coaxial cable is used to make connection between the drive element and the effective coil structure. In the embodiment shown, oppositely positioned conductors each connect to an outer conductor of the coaxial cable while alternately positioned conductors connect to an inner conductor of the coaxial cable. In this fashion, only two separate current paths extend above the effective coil structure through the coaxial cable.

FIG. 6i illustrates an alternative termination and shield structure 880 for connecting a source or termination to the effective coil structure of a coil layer 32. Two conductors pass through a central portion of the cylindrical structure 880 to the coil layer and feed separate coil segments. Further, two conductors of the coil structure connect to an external portion of the cylinder and provide current flow in an opposite direction. In this fashion, electric fields between the oppositely directed current lines are minimized and a shielding effect is provided.

FIG. 6j illustrates a termination and shield configuration providing connectivity and shielding to each of four conductor segments extending from a common boundary point at a corner of four adjacent effective coils 47. The structure 890 effectively shields each of the conductors as they reach a common intersection point and provides current paths to feed the effective coil structure. In this fashion, the structure 890 not only provides a superior shielding performance at a corner of the effective coils but also provides rigidity to the coil structure itself.

FIG. 6k illustrates an drive element coupling structure 900 for driving the effective coil structure as illustrated in FIGs. 6a through 6e. The drive element coupling structure 900 preferably includes a first drive element layer 902 and a second drive element layer 906. The first drive element layer 902 operably couples to a first side of a drive element 910 and to a first end of each of the conductor segments at a plurality of coupling locations 904. The second drive element layer 906 operably couples to a second side of the drive element 910 and to a second end of each of the conductor segments at a plurality of coupling locations 906.

If the drive element coupling structure 900 is used in conjunction with the structure 800 of FIG. 6a, for example, the drive element 910 would inject current into conductor segments 802 from first ends 804 and remove the current from second ends 806 to cause the effective closed loop current at the effective coils 47. The effective closed loop current, in turn, produces the magnetic fields 50 and 52 in the coil layer 32. In a plasma generator embodiment, this drive element 910 preferably injects an alternating current to produce an alternating magnetic field at the effective coils 47. However, in the case of a plasma filter embodiment, the drive element 910 preferably injects a direct current or a combination of direct and alternating current. In some situations, the connection between the first drive element layer 902 and the second drive element layer 906 may simply be a passive connection or a switch depending upon the particular application to allow the effective closed loop current to flow in the effective coils 47. Such could be the case when in a plasma filter wherein plasma induces the magnetic fields and, resultantly, the effective closed loop current which allows the magnetic field to fluctuate.

At each junction location 904 or 908, a lumped circuit element 903 could be inserted between the drive element layer 902 or 906 and the conductor segments. In this fashion, the flow of current within the conductor segments could be tailored for each particular portion of the coil layer 32. The tailoring of current, and resultantly, magnetic field strength, is beneficial in creating a uniform plasma across the process chamber 36.

FIG. 6l illustrates an injection layer structure 920 that may be used to drive the coil layer 32 structures of FIGs. 6a through 6e. Preferably, a first drive element layer 922 of the structure 920 comprises a plate element, wherein the plate element operably couples to a first side of the drive element 928 and to first ends of each of the conductor segments at connection points 924. A second drive element layer 926 of the structure 920 is preferably a grid structure, operably coupling a second side of the drive element 928 to second ends of conductor segments at connections points 929.

Use of the plate structure of the first drive element layer 922 in conjunction with the structure 920 of FIG. 6l provides the important benefits of reduced resistance to the flow of electricity across the coil layer 32. Further, the plate structure of the first drive element layer 922 provides the benefit of dissipating heat generated within the conductor segments more efficiently than a grid structure would.

FIG. 6m illustrates an injection layer structure 930 for providing current drive or flow for the effective coil structures of FIGs. 6a through 6e. Preferably, the structure 930 includes a first drive element layer 932 constructed as a conductive plate element and a second drive element layer 936 also constructed as a conductive plate element. The first drive element layer 932 operably couples a first side of the drive element 940 to the first ends of the coil segments at junction points 934. The second drive element layer 936 operably couples a second side of the drive element 940 to second ends of each of the coil segments at junction points 938.

The second drive element layer 936 includes a plurality of holes 937 through which connections to the first drive element layer 932 pass. These holes 937 are commonly referred to as pass-through holes. Preferably, the conductors passing through the pass-through holes 937 are insulated from the second plate 936 so as to prevent an electrical arc between the wire and the plate 936. The plate elements of the structure 930 provide

minimized current flow resistance and improved heat dissipation as compared to prior structures.

The structures of FIGs. 6a through 6m each also provide the important benefits of reducing phase differentials across the effective coils 47. At high operating frequencies, the wavelength of an applied signal may approximate a length of a conductive path on which the applied signal propagates. At high operating frequencies, uneven magnetic field generation may be caused by phase differentials along a conductive structure, and resultantly, plasma generation is not uniform. By using the relatively shorter conductor segments and drive element layers of the structures illustrated, higher operating frequencies may be used without the related problems of the prior devices.

FIG. 7a illustrates a plasma shielding element 955 which at least partially surrounds at least one coil element 46. By surrounding the coil element 46, the plasma shielding element 955 reduces a capacitive coupling between the plasma and a respective coil element 46. Upon generation, plasma includes positively and negatively charged particles. Further, the plasma itself may be biased at a certain voltage. Because the coil elements are at a voltage level, they attract a portion of the plasma particles causing the plasma particles to strike the coil elements 46. The plasma shielding elements 955 partially surrounds the coil elements 46 to form a structure that provides a Faraday cage effect to shields the coil elements 46.

Preferably, the plasma shielding element 955 includes a connecting portion 954 that connects the shielding element 955 to a connecting grid 956 which, in turn, connects the plasma shielding elements 955 to one another. The connecting grid 955 preferably is also connected to a plasma shielding connection element (not shown) at a terminating end 958, the plasma shielding connection element selectively varying the voltage on the grid 956. Preferably, the plasma shielding connection element is selected from the group consisting of direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, passive circuit elements, active circuit elements, and switches.

Any charge collected by the shielding element 955 is redirected to the connecting point 958 so that the charge may be dissipated. In this fashion, the charge does not reach the coil elements 46 to heat the elements and disrupt their operation. The plasma shielding

elements 955 may be selectively biased with the plasma shielding connection element to prevent plasma 960 from approaching the coil elements 46. Such may be performed by holding the grid 956 at a voltage level relative to the plasma 960.

5 The plasma shielding structure 950 of FIG. 7a provides the important benefit of reducing parasitic capacitance between the coil elements 46 and the plasma 960. By reducing parasitic capacitance, bombardment of the effective coil elements 46 by the plasma 960 and bombardment of walls adjacent the coil layer 32 is reduced to prevent damage and heating. Therefore, components within the process chamber have an extended life cycle and operate more efficiently than they would otherwise.

10 FIG. 7b illustrates an alternative effective coil shielding structure 970 for shielding the coil elements 46 from plasma 960. The structure 970 preferably includes a plurality of U-shaped elements having a first side 972 and a second side 974 disposed substantially opposite one another such that a portion of a coil element 46 resides between the sections 972 and 974. As compared to the structure of FIG. 7a, the U-shaped structure is simpler  
15 to build and to implement in conjunction with the coil layer 32 of the present invention. However, the structure 970 provides the benefits that were also provided by the structure 950 of FIG. 7a.

The structures 950 and 970 of FIGs. 7a and 7b respectively are preferably constructed of a non-magnetic conductor that is coated with a dielectric layer. By using  
20 a conductor, the structures may be uniformly biased. By using a non-magnetic material, the magnetic fields generated by the coil elements 46 will be undisturbed by the structures. By coating the structures with a dielectric material, it prevents metal from being directly exposed to plasma, the metal potentially being damaged upon exposure to the plasma. In the applications of ashing, for example, the presence of exposed metal in the process  
25 chamber is not detrimental to the process. However, the etching processes and in the deposition process, the presence of exposed metal within the process chamber may contaminate the process. Thus, the dielectric layer prevents such contamination during a particular the process and use.

FIG. 8a illustrates a connectivity scheme 65 that may be used in conjunction with  
30 various embodiments of the present invention to produce the effective closed loop currents

48  $i_c$  in the effective coils 47. As shown, biasing voltage source 67 and alternating voltage source 66 provide a controlled voltage across the first plurality of parallel conductors 54. Biasing voltage source 68 and alternating voltage source 69 provide a controlled voltage across a second plurality of the parallel conductors 54. Preferably, alternating source 66 and alternating source 69 provide voltages to the parallel conductors 57 in phase to create equal currents in the parallel conductors that travel in opposing directions to create the effective closed loop currents. Further, the biasing voltages created by biasing sources 67 and 68 are supplied to generate a controlled electrical field between the conductors 54.

FIG. 8b illustrates an alternative connectivity scheme 70 that may be used in conjunction with various embodiments of the present invention to produce the effective closed loop currents 48 in the effective coils 47. As shown, alternating source 71 provides an alternating voltage across a first portion of the plurality of parallel conductors 54 in a first direction and across a second portion of the plurality of parallel conductors 54 in a second direction. Thus, alternating source 71 creates alternating currents  $i_c$  that travel in opposite directions in adjacent conductors 54 to create the effective closed loop current 48 in the effective coils of the conductors 54. Biasing source 73 provides a biasing voltage to the second portion of the parallel conductors 54 to set up electric fields between adjacent conductors 54. Further, compensating elements 72 are included to equalize current flows  $i_c$  in the individual conductors 54 or to otherwise adjust the operation of the coil layer 32.

FIG. 8c is a signal timing diagram illustrating applied conductor voltage 74, alternating source voltage 75, alternating effective closed loop current 76, alternating induced magnetic fields 77, alternating induced electric fields 78, and biasing voltages 78 applied to the plurality of conductors 54. These signals may be applied to the circuits of either FIG. 8a or FIG. 8b. In a first period of operation 79, the biasing voltage  $v_b$  78 is positive and resultantly, the applied voltage 75, equal to the alternating source voltage 75 plus the biasing voltage 78, is offset by the biasing voltage  $v_b$  78. The effective closed loop current 76 lags the applied voltage 74 due to the series inductance of the plurality of conductors 54. However, the effective closed loop current 76 may be offset in some cases by the application of the biasing voltage  $v_b$  78 to the plurality of conductors 54. The

magnetic fields 77 at the plurality of effective coils are approximately in phase with the effective closed loop current 76. The electrical fields 78 induced by the magnetic fields 76 are approximately 90 degrees phase leading as compared to the magnetic fields 77. The voltage differential  $v_b$  between the first portion and second portion of plurality of conductors is held at approximately  $v_b$ , a positive biasing voltage.

In a second period of operation 79', the biasing voltage  $v_b$  78 is negative and resultantly, the applied voltage 75, which equals the alternating source voltage 75 plus the biasing voltage 78, is offset by the biasing voltage  $v_b$  78 in the negative direction. The effective closed loop current 76 lags the applied voltage 74 due to the series inductance of the plurality of conductors 54. However, the effective closed loop current 76 may be offset in some cases by the application of the biasing voltage  $v_b$  78 to the plurality of conductors 54. The magnetic fields 77 at the plurality of effective coils are approximately in phase with the effective closed loop current 76. The electrical fields 78 induced by the magnetic fields 77 lead the magnetic fields 77 by approximately 90 degrees. The voltage differential  $v_b$  between the first portion and second portion of plurality of conductors is held at approximately  $v_b$ , a negative biasing voltage.

FIG. 9a illustrates an alternative construction 80 of coil layer 32 in accordance with the present invention. In the construction 80, the plurality of operably connected elements comprise a plurality of first conductors 82 and a plurality of second conductors 84. The plurality of first conductors 82 orient substantially parallel to one another and are preferably laid out equidistant across the coil layer 32. The plurality of second conductors 84 also orient substantially parallel to one another equidistant across the coil layer 32. The plurality of second conductors 84 are interwoven with the plurality of first conductors 82 to form the coil layer 32. The plurality of first conductors 82 and the plurality of second conductors 84 preferably are insulated with respect to one another so that their interwoven construction does not causes a conduction of current directly from a first conductor 82 to a second conductor 84 at crossing locations. Taken together, the first conductors 82 and second conductors 84 create a screen like structure across the coil layer 32. The interwoven nature of the structure 80 causes the effective coils 47 to be surrounded on two sides by the first conductors 82 and on two sides by the second conductors 84.

In conjunction with the plurality of first conductors 82 and plurality of second conductors 84, the apparatus further comprises a first drive element layer 85 and a second drive element layer 87. The first drive element layer 85 preferably couples to the drive element 34 to provide current or voltage from the drive element that produces the effective closed loop currents 48 at each of the effective coils 47. The first drive element layer 85 orients substantially parallel to the coil layer 32 and couples the drive element 34 to the plurality of first conductors 82 at first contact points 86. The first drive element layer 85 also couples the drive element 34 to the second conductors at second contact points 90. The first drive element layer 85 preferably is coextensive with a surface of the coil layer 32 so that it makes contact with the plurality of first conductors 82 and the plurality of second conductors 84 across the area of the structure 80.

Second drive element layer 87 operably couples to the drive element 34 and orients substantially parallel to the coil layer 32. The second drive element layer 87 couples the drive element 34 to the plurality of first conductors at third contact points 88. Further, the second drive element layer 87 couples the drive element 34 to the second conductors 84 at fourth contact points 92. Coupled in this fashion the first drive element layer 85 and second drive element layer 87 allow the drive element 34 to cause current flow in the first conductors 82 and the second conductors 84 as shown. In this fashion, from the contact points, current flows in two separate directions in each of the conductors 82 and 84. For example, from contact point 92, current flows in two directions from the second drive element layer 87 to the first drive element layer 85 at third contact points 90. The effective pattern of current flowing in the effective coils 47 results in the effective closed loop current 48 and causes the magnetic fields 40 and 52 in accordance with the present invention. In this fashion, the magnetic fields 50 and 52 may generate the plasma within the process chamber 32.

FIG. 9b illustrates a perspective view of a construction of the coil layer 32 illustrated in FIG. 9a. As shown, the first conductors 82 contact the first drive element layer 85 at first contact points 86 and contact the second drive element layer 87 at second contact points 88. As shown, the plurality of second conductors 84 contact the first drive element layer at third contact points 90 and contact the second drive element layer 87 at



fourth contact points 92. In this fashion, current is injected by the first drive element layer 85 and drained by second drive element layer 87 via the drive element 34. Of course, if the drive element 34 is alternating in nature, the drive element layers 85 and 87 alternatively inject and drain current on different portions of the cycle.

5 In the construction of FIG. 9b, the first drive element layer 85 and second drive element layer 87 sandwich the conductors 82 and 84. Because of the short paths from the drive element layers 85 and 87 to the conductors 82 and 84, the impedance of each path is minimized, the coil layer 32 may be operated at higher frequencies, variations in voltages at high operating frequencies due to phase displacements are minimized, and heat  
10 may be more easily removed from the coil layer 32. As with prior embodiments, lumped elements may be added to particular current paths to adjust the current flow in the coil layer 32 so that magnetic field 50 and 52 magnitudes are controlled.

FIG. 9c illustrates a perspective view of an alternative construction of the coil layer 32 illustrated in FIG. 9a. The structure of FIG. 9c differs from the structure of FIG. 9b  
15 in that the first drive element layer 85 and second drive element layer 87 reside on a same side of the conductors 82 and 84. Thus connections from the conductors 82 and 84 to the drive layer 85 and 87 both extend above the conductors 82 and 84. The construction of FIG. 9c provides the important benefit of providing drive current to the coil layer 32 from a common direction. In this fashion, the drive layers 85 and 87 could both reside outside  
20 of the process chamber 36 while the conductors 82 and 84 could reside inside the process chamber 36.

The simplified grid construction of FIGs. 9a, 9b, and 9c significantly reduces the cost associated with constructing a coil layer 32. Further, the constructions illustrated also reduce the overall impedance associated with driving a current in the coil elements 46  
25 associated with the coil layer 32.

The conductors of a coil layer 32 take various shapes, depending upon the particular application requirements. For example, conductors may be circular, flat, oval, oblong, or any other shape that provides advantages in the particular application due to the conductor's shape. For example, the electric field created by biasing adjacent flat  
30 conductors will better deflect the charged particles passing through the coil structure.

Thus, in some situations it may be advantageous to use flat conductors as opposed to round conductors and vice versa. Conductors having a cross section in the shape of an oval or an oblong section provide the benefit of having a smaller cross section facing plasma that bombards the coil layer 32. In this fashion, the oblong shape has a sufficient cross section to reduce the series impedance of the conductors but a smaller capture area to reduce the effective surface that the plasma bombards.

The spacing between conductors is critical in the construction of the coil layer 32. In a plasma filled environment, the plasma surrounds the conductors but maintains a sheath distance from the conductors. In the case of a grounded grid, the plasma sheath distance is determined by the potential of the plasma and the potential of the conductors. However, in the generation apparatus of the present invention, the plasma sheath distance is slightly larger because of the relatively larger magnetic fields created by the effective coils in the coil layer 32.

The spacing between conductors in the coil layer 32 is critical in determining how the coil layer 32 functions. When the distance between conductors is less than twice the plasma sheath distance, the plasma operates in what is called a "fast mode" wherein plasma particles passing between the conductor must align with an electric field between the plasma and the conductors. With respect to the coil layer 32 of the present invention 32, in the fast mode, charged particles must also align with the magnetic fields that are normal to the coil layer 32 surface.

In the "effusive mode", the spacing between adjacent conductors is greater than twice the plasma sheath distance for the particular plasma and plasma flows between conductors of the coil layer 32. However, the conductors of the coil layer 32 block a substantial high-energy portion of the plasma and allow only low energy plasma to pass. Thus, the plasma that does pass between conductors is a quiescent plasma.

In another mode of operation, the distance between adjacent coil elements or conductors is a middle distance apart such that the plasma passing between the conductors is not fully in the fast mode but not fully in the effusive mode either. In this mode, an effusive plasma flowing between the conductors is composed substantially of neutral particles. Particles having a charge within the plasma are attracted to the conductors of

the coil layer 32 and do not pass between the conductors. In this fashion, the apparatus of the present invention is used to neutralize the plasma passing through the coil layers 32.

FIG. 10 illustrates a construction of the coil layer 32 using a plurality of a elongated or flat conductors as the plurality of substantially parallel conductors 54. The conductors 54 are preferably bent and placed within the coil layer 32 such that their long lateral axes substantially align with a direction of magnetic field within the effective coils 47. The current is coupled to the conductors 54 such that the effective closed loop current is created at each of the effective coils 47. In this fashion, the magnetic field is created at each of the effective coils 47. The construction of the conductors 54 illustrated in FIG. 10 allows for a bias between conductors which create electric fields lateral to the magnetic fields in the effective coils 47.

The structure of FIG. 10 may be constructed as a plurality of operably connected plate elements disposed within the process chamber as well, wherein the plurality of plate elements are adjacently spaced to form a plurality of passages at the effective coils 47. The plurality of passages form a filtering region wherein the magnetic fields induced at the effective coils 47, via the Lorentz effect, causes charged particles to be drawn to the plate elements. A drive element 34 couples to the plurality of plate elements to produce the current in the plurality of plate elements to induce a magnetic field in each of the plurality of passages. Because of the construction of the plate elements and the excitation by the drive element, a magnetic field in each passage orients substantially parallel to a longitudinal direction of the passage such that positive ions and electrons of the plasma are directed by the magnetic field to filter and neutralize the plasma.

Preferably, the plate elements are biased by a biasing source to induce an electric field in each of the plurality of passages. The electric field in each passage orients substantially perpendicular to the longitudinal direction of the passage such that plasma ions and electrons are directed by the electric field toward the plate elements. In this fashion, the structure of FIG. 10 produces both a filtering function and a neutralization function when selectively biased and excited. Further, the structure acts as columnar for aligning particles in a direction perpendicular to the substrate for anisotropic processing.

FIG. 11 illustrates an apparatus 100 for generating a surface treating plasma 38 within a process chamber 36. The apparatus 100 preferably comprises a plurality of operably connected coil elements forming the coil layer 32. The coil layer 32 has been discussed in detail previously and will not be discussed with reference to FIG. 11. However, the coil layer 32 of FIG. 11 is disposed within a containing housing 106 placed atop the process chamber 36. Preferably, the containing housing 106 attaches to an outer surface of the process chamber 36 to form a housing volume. The coil layer 32 is then contained within the housing volume 108. Further, the housing volume 106 preferably contains a dielectric liquid 104 that immerses the plurality of operably connected coil elements within the coil layer 32. The dielectric liquid 104 operates to cool the coil layer 32 as well as to reduce the capacitive coupling between the coil layer 32, the plasma 38, and the process chamber 36. Preferably, the dielectric liquid 104 facilitates the operation of coil layer within the containing housing 106.

The drive element 34 excites the coil layer 32 as previously discussed. A window 102 separates the containing housing 106 from the process chamber 36 and preferably comprises a crystalline material that allows the magnetic fields created by the coil layer 32 to extend into the process chamber 36 to generate the plasma 38. In some applications, the coil layer 32 would not reside within the process chamber 36 because of the type of process being performed within the process chamber 36. Thus, the apparatus 100 of FIG. 11 provides the important advantages that were provided by the apparatus 30 of FIG. 3 as well as the important advantages of not intruding into the process chamber 36. In this fashion, the apparatus 100 of FIG. 11 creates a uniform and quiescent plasma 38 within the process chamber 36 to perform a uniform etching, ashing, or deposition upon the substrate 40 held in the chuck 42 contained within the process chamber 36.

FIG. 12 illustrates an apparatus 120 for treating a substrate 130 with a surface treating plasma 128 having an alternative construction. The apparatus 120 comprises a process chamber 126, a chuck 132, a gas injector 134, a plurality of operably connected coil elements forming the coil layer 122, and a drive element 124. The apparatus 120 preferably also includes a vacuum system 136. The process chamber 126 may be sealed to isolate an inner portion of the process chamber 126 from the environment. The chuck

132 disposed within the process chamber 126 supports the substrate 130 for so that it may be treated by the plasma 128. The gas injector 136 injects a treating within the process chamber. Fluorine or chlorine is typically injected into the process chamber 126 and then energized to create the surface treating plasma 128.

5           As previously discussed, the coil layer 122 comprises the plurality of coil elements that form the plurality of effective coils and that are adjacently spaced apart to form the coil layer 122. The structure of the operably connected coil elements may take a form previously described or any structure within the scope of the present invention that produce the magnetic fields at the effective coils. The coil layer 122 shown in FIG. 12 surrounds  
10 a portion of the process chamber 126 in a dome-like fashion. The coil layer 122 may be formed in any of various shapes so as to conform to the requirements of the process chamber and the process being executed within.

          While the coil layer 122 is shown to reside on an outer surface of the process chamber 126, the coil layer 122 may also be disposed within the process chamber 126, on  
15 an inner surface or in another location depending upon the particular requirements of the process. The coil layer 122 could also be formed to fully surround the process chamber 126. The location and shape as well as construction of the coil layer 122 determines a magnetic field strength within the process chamber as well as outside the process chamber. Thus, depending upon the particular magnetic field strength and plasma generating  
20 requirements of the apparatus 120 of the present invention, the coil layer 122 may take various shapes to produce the desired results.

          As has previously been discussed, the drive element 124 is selected to produce desired currents and voltages in the coil layer 32 and resultantly to produce the magnetic and electric fields within the process chamber 126. The drive element 124 may comprise  
25 an alternating source, direct source, or a combination of both to produce the plasma 128 within the process chamber in a manner that will effectively surface treat or diffuse the substrate 130 within the process chamber 126.

          Thus, the apparatus 120 illustrated in FIG. 12 provides important advantages over the prior devices. It generates a uniform and quiet plasma within the process chamber 126  
30 without creating large magnetic fields on the substrate 130 thereby minimizing EMF

coupling and damage. Further, because the magnetic fields created by the coil layer 122 extend only proximately around the coil layer 122, the magnetic field will not affect the operation of sensors located around the process chamber 126. Additionally, because the magnetic fields extend proximately around the coil layer 122, the fields created by the coil layer 122 are not affected by changes in the environment external to the process chamber 126.

FIG. 13 illustrates an apparatus 140 for treating a substrate 130 with a surface treating plasma 128. The apparatus comprises a process chamber 126, a chuck 132 disposed within the process chamber 126, a plurality of operably connected coil elements formed into a coil layer 142, a drive element 144, a plasma filter 146, an accelerator grid 148, and a controller 147. The process chamber 126 is of a type previously discussed and will not be discussed further with respect to FIG. 13. The chuck 132 resides within the process chamber and supports the substrate 130. Preferably, the chuck 132 is of a type known and will not be further discussed with reference to FIG. 13.

The coil layer 142 and drive element 144 are of a type previously described with reference to the FIGs. The coil layer 142 operates in conjunction with the structure previously described and receives current or voltage from the drive element 144 to create magnetic fields at each of the effective coils in the coil layer 142 to produce the plasma 128 within the process chamber. Preferably, the spacing of the effective coils in the coil layer 142 is such that a quiescent plasma may pass through the effective coils. In this fashion, plasma 128 generated on both sides of the coil layer 142 is substantially quiet.

The plasma filter 146 is preferably a grid, wherein the grid passes a quiet plasma 148. Preferably, the plasma filter 146 operates in a manner consistent with the principles previously described to filter the plasma 128 generated by the coil layer 142. The filter 146 may receive a voltage or current from the controller 147 or may be passively connected at a fixed voltage level, the voltage of the process chamber 136, or the voltage level of the chuck 132 so that the filter 146 may provide the filtering function. The filter 146 orients substantially parallel to the coil layer 142 such that plasma 128 passing from coil layer 142 toward the substrate 130 will pass through the filter 136. Therefore, on a

side of the filter 146 opposite the coil layer 142, a filtered quiet plasma is produced that may be further operated upon before it treats the substrate 130.

Accelerator grid 150 preferably is also substantially parallel to the coil layer 142 and resides within the process chamber 126. As is shown, the plasma accelerator  
5 preferably resides between the coil layer 142 and the chuck 132 to selectively accelerate plasma particles 128 within the process chamber 126 from the plasma filter 146 toward the substrate 130. Controller 147 selectively biases the plasma filter 146 and the  
10 accelerator grid 150 to produce the acceleration function. By selectively biasing the filter 146 and the accelerator grid 150 with respect to each other, or with respect to the plasma 128 and the substrate 130, charged particles, both ions and electrons, are selectively accelerated/decelerated toward the substrate 130.

Numerals 148 refers to positively charged ions, negatively charged ions, and negatively charged electrons residing between the filter 146 and the accelerator grid 150. The application of an electric field between the filter 146 and the accelerator grid 150  
15 accelerates the charged particles, the acceleration of the differently charged particles depending upon the biasing applied to the filter 146 and accelerator grid 150. However, ions having a positive charge have a much greater mass than electrons that do electrons having a negative charge. Thus, the selective biasing of the accelerator grid 150 and filter  
20 146 by the controller 147 must be carefully performed so as to selectively accelerate the particles to cause the particles to achieve a uniform velocity. When the positively charged ions and negatively charged electrons have approximately the same velocity, many will recombine to form neutral species. Preferably, the surface treatment of the substrate 130 with the plasma 128 will occur with these neutral species 152. When the substrate 130 is treated with neutral species, charge created on the surface of the substrate 130 will be  
25 minimized since no external charge is added to the substrate 130 via the positively charged ions and negatively charged electrons.

However, the accelerator grid 150 and plasma filter 146 may be biased such that the particles 148 obtain great velocity. Even if the accelerated particles recombine to form neutral species, if they have more energy than 20 electron volts (eV), when they collide  
30 with the substrate 130 surface, they may dislodge an electron from a silicon atom or other

semiconductive surface and damage the substrate. This dislodging of surface electrons is called secondary electron generation. Such secondary electron generation is harmful to the surface of the substrate 130 and can cause charge induced damage. Thus, in the operation of the accelerator grid and plasma filter 146, particles must not be accelerated to such a great velocity as to cause secondary electron generation.

The chuck 132 may also be biased at an alternating voltage level to cause an electric field between the substrate 130 engaged by the chuck 132 and the plasma 128 within the process chamber 126. By inducing the electric field between the substrate 130 and the plasma 128 through the filter 146 and accelerator 150, the ions within the plasma 128 may be further accelerated in a direction normal to the surface of the substrate 130 to perform an anisotropic etching process.

In many processes it is required that no ultraviolet light be provided to the substrate 130. However, since the plasma 128 generates ultraviolet light, the ultraviolet light must be blocked out prior to its reaching the substrate 130. One manner in accomplishing blocking the ultraviolet light is to create a grid of conductors having substantially flat shape. The grid may be constructed such that the wires with the flat shape stand on end so that a plurality of passages are formed through the grid. The passages each have length such that the grid has a thickness. By selectively placing two adjacent grids non-parallel to one another, and placing the grids such that they neither one is parallel to the substrate, the line of sight between the plasma 128 and substrate 130 may be defeated. In this fashion, the UV rays are blocked by the dual grid structure wherein the dual grids each have the passages. However, the dual grid structure will not block the flow of ions and electrons and neutral species from the plasma 128 to the substrate 130. The dual grids will simply block the ultraviolet light from application to the substrate 130.

A coil layer 142 functioning as a plasma filter 146 of an accelerator grid 148, may also be used to block the line of sight between the plasma 128 and substrate 130. By constructing the coil elements within the coil layer 142 using flat conductors, passages may be created in the coil layer 142 such that one passage resides in each effective coil. Using two coil layers 142 adjacent to one another, the line of sight between the plasma 128 and



the substrate 130 may be defeated to prevent the application of UV light to the substrate 130.

The structure of the apparatus 140 shown in FIG. 13 may be characterized as a generation, filtration, and neutralization system for the surface treatment of the substrate 130 within a quiet plasma 128. Thus, the teachings relating to the apparatus 140 apply not only to the generation, but to the filtering and to the neutralization of plasma as well. Because of the unique construction of the apparatus 140, the plasma 128 that is initially generated is substantially less noisy than the plasmas created by the prior devices. The coil layer 142 does not create large magnetic fields within the process chamber 126 to cause EMF coupling to the substrate 130 and causes little or no magnetic field generation external to the process chamber 126 that may affect sensor operation or be affected by changes in the external environment.

The apparatus 140 of FIG. 13 may be used in any type of plasma process, including surface etching, ashing, diffusion, and/or deposition. The benefits provided by the apparatus 140 extend to any of the processes that may be performed by the apparatus 140.

FIG. 14 illustrates an apparatus 200 for generating a surface treating plasma 128 within a process chamber 126 and for directing plasma 128 away from the walls of the process chamber 126. The apparatus 200 preferably comprises a plasma source 202, a coil layer 206, and a drive element 208 operably coupled to the coil layer 206.

The plasma source 202 preferably is powered by an electrical source 204 of a type previously described herein. The plasma source 202 may comprise any various type of plasma source 202 that couples through a window 203 to an internal portion of the process chamber 126. While the construction of the plasma source 202 may comprise that of the present invention, it may comprise a prior art source as well. Through the window 203, the plasma source 202 generates the plasma 128 within the process chamber 126. The plasma 128 provides surface treatment to the substrate 130 which is engaged in the chuck 132.

The coil layer 206 preferably extends around an inner wall of the process chamber 126. However, the coil layer 206 could extend around an outer wall of the process

chamber 126. In either case, a magnetic field created by the coil layer 206 directs plasma particles generated within the process chamber 126 away from the inner surface of the process chamber 126. Preferably, the coil layer 206 comprises a plurality of operably connected coil elements disposed along an inner surface of the process chamber 126. The plurality of operably connected coil elements form a plurality of effective coils that are adjacently spaced apart to form the coil layer on a surface of the process chamber 126.

The structure of the coil layer 206 may be identical, or substantially similar to, the previously described coil layers used to generate surface treating plasma 128 within the process chamber. However, depending upon the spacing between the effective coils in the coil layer 206 and the energization of the coil layer 206 by the drive element 208, plasma 128 is directed away from an inner surface of the process chamber 126. As was previously described, the spacing between the conductors comprising the coil layer 206 determines how and if plasma passes through the coil layer 206. If the conductor spacing associated with the effective coils is small, plasma will be directed away from the inner walls of the process chamber 126. Such will be the case independent of the placement of the coil layer 206 whether it is external to the process chamber 126 or internal to the process chamber 126.

The magnetic fields created by the effective coils of the coil layer 206 will deflect the path of traveling charged particles based on the Lorentz force. The Lorentz force will alter the path of the charged particles such that the particles either spiral into a conductor of the coil layer 206 or are repelled back toward the center portion of the process chamber 126 away from the coil layer 206. Alternatively, or in conjunction with the application of the drive element 208 to create the magnetic fields, the coil layer 206 may be selectively biased to increase their repulsion of plasma 128 particles.

Thus, the apparatus 200 of FIG. 14 provides the important benefits of reducing contamination within the process chamber 126, reducing consumption of plasma by a silicon liner that would otherwise be placed on the inner wall, and reducing degradation of the process chamber walls themselves. Because the coil layer 206 repels plasma 128 from the walls of the process chamber 126, less energy from the plasma 128 is lost to collisions with the walls and the process operating is more efficient. Further, the

apparatus 200 prevents a drop in intensity of the plasma 128 near the walls of the process chamber 126. Thus, the apparatus 200 of FIG. 14 allows for a more dense plasma 128 to be created within the process chamber as well as equalizing the intensity of the plasma 128 across the process chamber 126 thus allowing for a more uniform plasma etching, deposition, diffusion, and/or ashing process within the process chamber 126.

FIG. 15 illustrates an apparatus 250 for producing a uniform and quiescent surface treating plasma 262 within a process chamber 126 in an alternative form. The apparatus 250 comprises a plasma source 252 and a plasma filter 256. The plasma source 252 generates a noisy plasma 254 within the process chamber 126. The noisy plasma 254 includes particles 260 that are both positively and negatively charged.

The plasma filter 256 is disposed within the process chamber 126 and filters the noisy plasma 254 to create a quiet plasma 262 that eventually treats the substrate 130. A coil layer 257 of the plasma filter 256 separates the first portion of the process chamber 255 from a second portion of the process chamber 259. The coil layer 257 preferably comprises a plurality of operably connected coil elements wherein the plurality of operably connected coil elements form a plurality of effective coils disposed within the process chamber 126. The plurality of effective coils are adjacently spaced apart to form the coil layer 256. The construction of the filter coil layer 257 is either identical or substantially similar to constructions of the coil layers discussed previously.

In one form of the apparatus 250, the filter coil layer 257 includes at least one passive connection wherein the passive connection allows the plasma to produce a current in the plurality of effective coils. The induction of current in the plurality of effective coils by the plasma induces the magnetic fields at each of the plurality of effective coils. Upon the creation of the magnetic fields, the magnetic field filters the plasma to allow only the quiet plasma 262 to flow to the second portion of the process chamber 257. Alternatively, the passive connections could connect the filter coil layer 256 and the components of such to the walls of the process chamber 126. These connections as well allow current to flow in the effective coils to create the magnetic fields. Thus, the filter coil layer 257, when operably connected via passive connections performs a filtering function without being actively driven.

The filter coil layer 257 may be actively driven as well by a drive element 258 to produce the currents in the effective coils and generate the magnetic fields at the effective coils. Such a technique has previously been inscribed. However, the magnitude and shape of signals driving the filter coil layer 257 will vary depending upon the application. Thus, the voltages or currents applied to the filter coil layer 257 in conjunction with the apparatus 250 of FIG. 15 will differ from those driving the coil layer 32 of FIG. 13 because of the function of the filter coil layer 257. Since the filter coil layer 257 is not intended to generate plasma within the process chamber 126, the strength of the magnetic fields in the filter coil layer 257 will be less than those that are required to generate a plasma within the process chamber. Preferably, the actively driven coil layer 257 will be driven at a DC current. Driving the filter coil layer 257 with a DC current creates no time varying magnetic fields but only non time varying magnetic fields at the effective coils. Such non-varying magnetic fields will not generate plasma 254 within the process chamber 126 but will deflect charged particles approaching the filter coil layer 256 based upon the Lorentz force. Thus, the filter coil layer 256 will allow substantially only neutral particles to pass through the filter coil layer 256 to become the quiet plasma 262.

The filter coil layer 257 could be driven by a square wave as well, the square wave having a relatively long period such that generated magnetic fields vary at a slow frequency. Effectively, the generated magnetic field is direct in one direction for a period of time and direct in an opposite direction for another time period. In certain processes, an energization of the coil layer 256 in this manner allows charged particles with a certain charge to pass during one phase of the energization and charge particles having an opposite charge to pass during a second phase of the energization. Such a technique could be used in the recombination process among others.

Thus, the apparatus 250 of FIG. 15 provides the important benefit of producing a quiescent plasma to treat a substrate 130 in conjunction with a noisy plasma generator. The apparatus 250 could be applied to prior art plasma generation equipment to selectively filter the noisy plasma 254 to create the quiescent plasma 262 for treating the substrate 130. The construction of the filter coil layer 257 performing the filtering reaps the substantial benefits at relatively low cost.

FIG. 16 illustrates an apparatus 300 for producing a uniform and quiescent surface treating plasma for treating a substrate 130 held within a chuck 132 in a process chamber 126. The apparatus 300 includes a generator coil layer 302 driven by a drive element 304, a filter coil layer 304 driven by a drive element 306, and accelerator grid 306 driven by a biasing source 308, and an additional filter coil layer 310 driven by a drive element 312. Each of the coil layers 302, 304, and 310 within the process chamber 126 is preferably constructed in a manner consistent with the structures previously discussed. The generator coil layer 302 driven by the drive element 304 generate a substantially uniform plasma 128 in a first portion of the process chamber. The generator coil layer 302 will be driven by the drive element in a manner consistent with those previously described such that the generator coil layer 302 generates the plasma 128 within the process chamber 126.

Filter coil layers 304 and 310 are driven by drive elements 306 and 312 respectively. Preferably, the filter coil layer 304 and filter coil layer 310 are constructed in a manner consistent with the structure previously described with reference to the FIGs. Thus, all three oil layers 302, 304, and 310 include a plurality of coil elements that form a plurality of effective coils, with the effective coils adjacently spaced apart to form the respective coil layer. The effective coils are either driven by a drive element or terminated such that effective closed loop currents will flow in the effective coils to generate magnetic fields at each of the effective coils. Of course, drive element 304 will drive the generator coil layer 302 to generate the plasma 128. However, each filter layer 304 and 310 may either be passively terminated or driven by a respective drive element so that the filter layers 304 and 310 perform a filtering function.

Preferably, the second filter coil layer 310 is selectively biased such that it has strong electric fields between adjacent coil elements within the filter coil layer 310. These strong electric fields significantly filter out charged particles in the accelerated plasma 307 to produce substantially neutral particles in the secondarily filtered plasma 309 prior to its application to the substrate 130.

On a side of filter coil layer 302 opposite the generator coil layer 304, filtered plasma particles 305 will be produced. The accelerating grid 306 is selectively biased by biasing source 308 to create electric field between the plasma 128, the first filter coil layer

304, and the second coil layer 310. In this fashion, the electric fields created by the selective biasing accelerate and decelerate the ions and electrons 305 toward the substrate 130 depending upon the particular biasing. Accelerated particles 307 on a side of the accelerating grid 306 adjacent to substrate 130 travel at a differing velocity than the particles on an opposite side of the accelerating grid. The accelerated particles 307 then are filtered by the second filter coil layer 310 to further filter the plasma prior to its application as filtered and accelerated plasma 309 to the substrate 130.

Thus, the apparatus 300 illustrated in FIG. 16 may be used in deposition, etching, diffusion, and/or ashing processes with the operation of the apparatus 300 tailored to the particular requirements of the process. The multiple filter structure illustrated in apparatus 300 provides significant filtering benefits as compared to a single filtering structure. Thus, the apparatus 300 of FIG. 16 provides the same benefits as previously described plus the additional benefits of further processing of the plasma 128 prior to its application to the substrate.

FIG. 17 illustrates a plasma filter and accelerator/decelerator apparatus 350 for filtering and accelerating plasma particles passing from a first portion 255 of the process chamber 126 to a second portion 257 of the process chamber. The apparatus 350 comprises a plasma filter 352 and a plasma accelerator/decelerator grid 354 disposed substantially parallel to and adjacent the plasma filter 352. The plasma filter 352 preferably comprises a filter coil layer which includes a plurality of operably connected coil elements formed into the plurality of effective coils that are adjacent spaced apart to form the coil layer. The construction of the plasma filter 352 is consistent with the structures previously described for the coil layers. Thus, the construction of the coil elements to form the effective coils within the plasma filter coil layer is consistent with those previously discussed in conjunction with the figures. Preferably, the plasma filter coil layer 352 separates the first portion 255 of the process chamber 126 from the second portion 257 of the process chamber 126.

Contained in the first portion of the process chamber 255 is a noisy plasma 254 formed by a plasma source 252. A particular structure of the plasma source 254 could be a prior art structure such as a magnetically induced plasma generator or any other plasma

generation structure. Types of structures used to generate the noisy plasma 254 within the process chamber 126 may include electron cyclotron resonance plasma generator, helical resonating generator plasma, capacitive coupled plasma generator, inductively coupled plasma generator, and magnetically enhanced reactive ion etching plasma as well as plasma generated by a surface wave. Any of these types of plasma generators will produce the noisy plasma 254 within the first portion 255 of the process chamber 126.

The plasma filter 352 filters plasma passing from the first portion 255 of the process chamber 126 to the second portion 257 of the process chamber 126 to produce a filtered plasma 262 in the second portion 257 of the process chamber. Preferably, the plasma filter 352 is constructed in a manner identical or similar to the plasma filter structure 304 described in conjunction with FIG. 16 or in another manner consistent with the present invention to perform the desired plasma filtering function.

Once the filtered plasma 262 has passed to the second portion 257 of the process chamber, the plasma accelerator/decelerator grid 354 acts on the plasma to accelerate/decelerate the plasma 262 toward the substrate 130. The accelerator/decelerator grid 354 is disposed substantially parallel to the plasma filter coil layer 352 and is selectively biased by the drive element 358 with respect to the plasma filter 352 such that the accelerator/decelerator grid 354 along with the plasma filter 352 causes plasma particles 262 to accelerate from the first portion of the process chamber to the second portion of the process chamber and strike the substrate 130. The accelerator/decelerator grid 354 may comprise a mesh of a type that is biased by the drive element 358. However, the accelerator/decelerator grid 354 could comprise a coil layer of the type discussed previously that also provides a filtering function.

Drive element 356 provides the driving current or voltage to the plasma filter 352 to causes the plasma filter 352 to provide the filtering function. The drive elements 356 and 358 in conjunction with one another will bias the plasma filter 352 and accelerator/decelerator grid 354 to cause the desired acceleration functions and produce an accelerated and filtered plasma 263 that will be used to treat the substrate 130. The biasing circuitry in the drive elements 356 and 358 may comprise direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, and may

as well include passive circuit elements and active circuit elements switches based upon the particular requirements of the application.

Thus, the apparatus 350 of FIG. 17 provides the important benefit of filtering a noisy plasma 254 to produce a filtered plasma 262 and accelerating the filtered plasma 262 to produce the filtered plasma 263 used to treat the substrate 130.

FIG. 18a illustrates an apparatus 400 for filtering and neutralizing plasma particles within a process chamber 126. The apparatus 400 comprises a plasma filter 402 including a filter coil layer 403 and a drive element 404 for energizing the filter coil layer 403. The apparatus 400 also comprises a plasma neutralizing grid 408 and plasma neutralizing circuitry 410 driving the plasma neutralizing grid 408. Noisy plasma 254 is generated within the process chamber 126 by a plasma source 252. The noisy plasma 254 is formed in a first portion 255 of the process chamber 126. The noisy plasma 254 is of a type that could cause significant damage to the substrate 130 if it was allowed to directly treat a substrate 130 held in a chuck 132 in the process chamber 126.

The plasma filter 402 is disposed in the process chamber 126 such that it separates the first portion 255 of the process chamber 126 from the second portion 257 of the process chamber 126 and filters plasma passing from the first portion 255 to the second portion 257 of the process chamber 126. The plasma filter 402 comprises a plurality of operably connected coil elements that form a plurality of effective coils adjacently spaced apart to form a coil layer separating the first portion of the process chamber 255 from the second portion 257 of the process chamber 126. The drive element 404 operably couples to the plurality of operably connected coil elements to produce an effective closed loop current at each of the plurality of effective coils. The effective closed loop current induces the magnetic fields filtering the noisy plasma 252 to produce a quiet plasma 406. The quiet plasma 406 comprises not only neutral species but also positively and negatively charged ions and electrons. Thus, the quiet plasma 406 does have some charge after passing through the plasma filter 402 and can damage the substrate 130 if excessively charged. However, in accordance with the present invention and the previous discussions relating to the plasma filter 402 of the present invention, significant charge reduction in the quiet plasma 406 has occurred in its passage through the plasma filter 402.



The plasma neutralizing grid 408 is disposed substantially parallel to the coil layer 403 of the plasma filter 402. The plasma neutralizing grid 408 may comprise simply a mesh structure or it may comprise a coil layer of the present invention as has been previously described in detail. The plasma neutralizing circuitry 410 selectively biases the plasma neutralizing grid 408 with respect to the plasma filter 402 such that the plasma neutralizing grid 408 along with the plasma filter 402 accelerate/decelerate the plasma electrons and plasma ions so that they reach a substantially identical velocity directed toward the substrate 130 substantially perpendicular to a surface of the substrate 130. When the electrons and ions have reached a substantially identical velocity they substantially recombine to form neutralized particles or species. Resultantly, a substantially neutral 412 particle species bombard the substrate 130 contained in the chuck 132 thus minimizing damage caused by the plasma.

Preferably, the neutralizing grid 408 and/or the plasma filter 402 coil layer 403 are selectively biased with respect to the noisy plasma 254 as well to aid in the neutralization process by removing charged particles from the filtered plasma 406. Further, the spacing of the neutralizing grid 408 is optimized to neutralize plasma particles passing through the grid 408.

In accordance with the present invention, the neutralizing grid 408 preferably comprises a coil layer constructed such that a plurality of effective coils are created, each of the effective coils generating a magnetic field. Prior art neutralizing grids typically comprised meshes that attempted to collect or attract all of the ions contained within the plasma passing near or through the grid thereby collecting significant positive or negative charge. Resultantly, significant current had to be bled off or provided depending upon the type of charge that was collected.

Prior art neutralization grids, in order to increase the likelihood that all or substantially all of the charged particles would be captured by the grid and only neutral particles would pass through the grid, had relatively small holes that allowed particles to pass. Because the holes were small in size, however, the cross-sectional capture area of the grid increased substantially so that even greater charge was captured by the grid. The large current source and drain requirements for the grid resulted in a significant sizing of

the biasing or supply circuitry connected to the neutralizing grid. The large cross-sectional capture area further increased the requirement of thickness of the grid, increasing the cost of the grid.

Further, with a large cross-sectional capture area, the prior art neutralizing grids blocked significant portions of the neutralized particles traveling toward the substrate 130, thus reducing the application rate of the plasma to the substrate 130. Such a reduced rate required a higher density plasma to be created within the chamber to increase the final application rate. This higher density of plasma generation within the first portion of the process chamber 255 even further increased the charge that was captured by the neutralizing grid.

However, in conjunction with the apparatus 400 of FIG. 18a, when the neutralizing grid 408 is constructed such that the plurality of effective coils create magnetic fields around the neutralizing grid 408, charged particles are directed away from the conductors based upon the Lorentz force. Thus, the conductors associated with the effective coils of the neutralizing grid 408 capture a very small amount of charge and require a small source current. Thus, smaller conductors can be used in the neutralizing grid 408 than with prior devices. However, because of the magnetic fields created by the neutralizing grid 408, the openings between conductors forming the grid 408 can be great while charged particles are still significantly deflected. Thus, the effective opening area for neutral particles through the neutralizing grid 408 is substantially larger than in the prior art devices while the effective opening area for charged particles through the neutralizing grid is still small. Resultantly, more neutralized particles pass through the neutralizing grid 408 to treat the substrate 130. A reduced intensity plasma 254 generated in the process chamber 126 causes an equivalent number of neutral particles to strike the substrate 130. The apparatus 400 of the present invention significantly increases the efficiency of the process in which it operates.

FIGs. 18b illustrates a selective biasing signals applied to the filter coil layer 402 and the neutralizing grid 408 of FIG. 18a in order to perform a selective acceleration and neutralization of plasma particles.  $V_{cn}$  412 represents the voltage applied across the filter coil layer 402 and the neutralizing grid 408. The application of a voltage across the grids

establishes an electric field between the grids.  $V_{cp}$  414 represents the voltage of the filter coil layer 402 with respect to the plasma 254 created in the first portion 255 of the process chamber 126. Electron or negative ion 416 portions of FIGs. 18b and 18c indicate the movement of electrons and negatively charged ions within the process chamber 126.

5 Positive ion 418 portion of FIGs. 18b and 18c indicate the movement of positively charged ions within the process chamber 126.

During time periods 413 and 417,  $V_{cn}$  is ramping negative and  $V_{cp}$  414 is ramping positive towards zero. During these time periods, electrons and negative ions 416 are extracted from the plasma 254 and accelerated from the filter coil layer 402 to the neutralizing grid 408. Further, during this time period, positive ions 418 are decelerated

10 away from the filter coil layer 402 toward the neutralizing grid 408.

During time periods 415 and 419,  $V_{cn}$  has ramped positive and  $V_{cp}$  414 is ramping down below zero. During these time periods, electrons and negative ions 416 are decelerated from the filter coil layer 402 to the neutralizing grid 408. Further, during this

15 time period, positive ions 418 are extracted from the plasma 254 and accelerated from the filter coil layer 402 toward the neutralizing grid 408. When the electrons slow until they have a substantially equal velocity to the positively charged ions, they will recombine to form neutral particles traveling towards the substrate. Once the neutral particles form, they are unaffected by the electric field between the filter coil layer 402 and the

20 neutralizing grid 408. Thus, the application of signals as illustrated in FIG. 18b causes the recombination of charged plasma particles while directing the resultant neutral species toward a substrate to be treated.

FIG. 18c illustrates alternative selective biasing signals applied to the filter coil layer 402 and the neutralizing grid 408 of FIG. 18a in order to perform a selective

25 acceleration and neutralization of plasma particles. During time periods 421 and 425,  $V_{cn}$  has ramped positive and  $V_{cp}$  414 is ramping down below zero. During these time periods, electrons and negative ions 416 are decelerated from the filter coil layer 402 to the neutralizing grid 408. Further, during these time periods, positive ions 418 are extracted from the plasma 254 and accelerated from the filter coil layer 402 toward the neutralizing

grid 408. During these time periods, the positive ions have a greater velocity than do the electrons during this time period.

During time periods 423 and 427,  $V_{cm}$  has gone negative and is still negative but ramping positive while  $V_{cp}$  414 is negative but ramping positive towards zero. During these time periods, electrons and negative ions 416 are extracted from the plasma 254 and accelerated from the filter coil layer 402 to the neutralizing grid 408. Further, during these time periods, positive ions 418 are decelerated slightly from the filter coil layer 402 toward the neutralizing grid 408. When the electrons accelerate until they have a substantially equal velocity to the positively charged ions, they will recombine to form neutral particles traveling towards the substrate. Once the neutral particles form, they are unaffected by the electric field between the filter coil layer 402 and the neutralizing grid 408.

In the case of FIG. 18b case, electrons or negative ions are extracted first, are accelerated, then slowed down while the positively charged ions are extracted and arrive later to recombine with the electrons. In the situation of FIG. 18c, positively charged ions are extracted and accelerated. Then, electrons are extracted and accelerated while positive ions are slightly slowed down so that the electrons arrive at the same velocity and recombine with the positive ions. Once created, the neutralized particles maintain the same velocity as the positively charged ion and electron upon recombination. Thus, neutral particles having a velocity identical to the charged particles may be used to treat the substrate 130 within the process chamber 126 anisotropically. These same principles may be applied for the recombination of negatively charged ions and positively charged ions to produce neutral particles within the process chamber 126.

Positively charged ions have a much greater mass than do electrons. Thus, the positively charged ions accelerate much more slowly in a given electric field than do electrons. Thus, the time varying bias will favor acceleration of the positively charged ions in a first direction as opposed to the electrons in the same direction. The wave shapes illustrated in FIGs. 18b and 18c are examples only and various techniques may be used to create the acceleration/deceleration and neutralization function. For example, various modulation techniques, duty cycles, and wave shapes may be employed to extract,

accelerate, decelerate, and/or neutralize the specific types of ions selectively with desirable energy chemical reactions and the profile of directionality.

The signals applied to the filter coil layer 403 and neutralizing grid 408 may cause the ions and electrons to recombine between the filter coil layer 403 and neutralizing grid 408. However, the signals could also be applied to cause the selective recombination of particles between the neutralizing grid 408 and the substrate 130. Further, in some situations, both positive ions and electrons may be accelerated/decelerated to arrive at the substrate 130 substantially simultaneously in substantially equal quantities distributed substantially uniformly across the surface of the substrate 130. Upon arrival, the charges of the positive ions and negative charges of the electrons neutralize one another in a process call quasi-neutralization.

The signals applied to the filter coil layer 403 and neutralizing grid 408 can be shaped so as to cause a dense electron cloud to form near the neutralizing grid 408. When a positive ion passes through this dense electron cloud, the probability that it will recombine with an electron to form a neutral particle is substantially increased.

The phenomenon stated above with respect to electrons may be applied to negatively charged ions as well. The negatively charged ions may be selectively accelerated and decelerated so that they combine with positively charge ions to form neutral particles. Of course, negatively charged ions has significantly greater mass than electron. Therefore, the timing and wave shapes applied to the apparatus 400 of FIG. 18a must be optimized to accomplish a selective recombination and neutralization.

FIG. 19 illustrates an alternative apparatus 450 for filtering and neutralizing plasma particles within a process chamber 126. The apparatus 450 preferably comprises a plasma filter 452 and plasma neutralizing circuitry 454 operably coupled to the plasma filter 452 to cause the plasma filter 452 to perform the additional function of neutralizing noisy plasma 254 to produce quiescent neutral plasma 412. Preferably, the neutralizing circuitry 454 includes a sensor for sensing a potential of the noisy plasma 254.

Noisy plasma 254 is generated by a plasma generator 252. The plasma filter 452 is disposed in the process chamber 126 and filters plasma passing from a first portion of the process chamber 255 to a second portion 257 of the process chamber 259. The plasma

filter 452 includes a plurality of operably connected coil elements that are constructed to create the plurality of effective coils that are in turn connected to create a coil layer. The coil layer of the plasma filter 452 is preferably identical to the structure of filters previously described in accordance with the present invention. Thus, the structure of the coil layer is not further described herein in conjunction with FIG. 19. Drive element 456 induces magnetic fields at each of the effective coils within the plasma filter 452 to cause the plasma filter 452 to have a plasma filtering function. Thus, the plasma filter 452 filters the noisy plasma 254 to produce a quiescent plasma 412 in the second portion 257 of the process chamber 126.

The plasma neutralizing circuitry 454 selectively biases the plasma filter 452, and the coil elements contained therein, with respect to the plasma 254 such that plasma electrons and ions of the plasma 254 accelerate toward and decelerate toward the plasma filter 452. The selective biasing of the plasma filter 452 causes at least a portion of the plasma electrons and plasma ions to obtain a substantially identical velocity and recombine to form neutral particles that will be used to treat the substrate 130. The plasma filter 452 is selectively biased with respect to the plasma in a manner similar, but not limited to, the manner discussed in conjunction with FIGs. 18b and 18c to cause electrons, negative ions, and positive ions traveling toward the plasma filter 452 to obtain a substantially identical velocity. Once they have obtained a substantially identical velocity, the plasma electrons and ions recombine to form neutralized particles resultantly forming a quiet and neutral plasma 412 that treats the substrate 130.

Thus, the apparatus 450 of FIG. 19 provides the important benefit of filtering and neutralizing a noisy plasma 254 to produce quiet and at least partially neutral plasma 412. Control provided by the neutralizing circuitry 454 and drive element 456 in conjunction with the structure of the plasma filter 452 provides superior performance in filtering and neutralizing at a lesser cost than prior devices and with a structure less complex than other embodiments of the present invention.

FIG. 20 illustrates an alternative construction 500 of the coil elements within a coil layer that is particularly useful in the filtering and neutralization of plasma within a process chamber. A first coil layer 502 and a second coil layer 504 orient substantially parallel

to one another to have a combining effect. The first coil layer 502 comprises conductors 508 and 510 oriented in a nonplanar fashion. The conductors 508 and 510 connected in a nonplanar fashion produce magnetic fields 512 and 514 that are parallel to an axis of their respective effective coils. As is illustrated in coil layer 502, however, the axes of adjacent effective coils substantially misalign with one another. In this fashion, none of the axes of the effective coils within the coil layer 502 are perpendicular to the coil layer 502 itself.

Depending upon the form of the effective closed loop current in the effective coils, the coil layer 502 acts to either filter, neutralize, and even generate plasma within a process chamber. In the case of a filtering operation, charged particles 506 traveling normal to the surface of the coil layer 52 are acted upon by the Lorentz force in all cases. Thus, the particular construction of the coil layer 502 of FIG. 20 significantly prevents the passage of charged particles through the coil layer 502 since they will likely not align with any magnetic field 512 or 514 within the coil layer 502.

The second coil layer 504 is preferably constructed in a manner similar to the first coil layer 502 such that conductors 516 and 518 produce magnetic fields 520 and 522. In accordance with the construction of the coil layer 504, adjacent magnetic fields produced by adjacent effective coils are substantially misaligned. Further, magnetic fields adjacent one another in the coil layers 502 and 504 preferably misalign so that the coil layers 502 and 504 prevent the passage of charged particles through the two coil layers 502 and 504. Thus, the coil layer construction illustrated in FIG. 20 provides the important benefit of eliminating the passage of traveling charged particles through the coil layers 502 and 504 independent of their travel path.

FIG. 21 illustrates a method 550 for generating a surface treating plasma within a process chamber for the etching, ashing, and cleaning of a substrate and the deposition upon a substrate. The method 550 commences at step 552 of operably connecting a plurality of coil elements within the process chamber. The connection of the coil elements produces a plurality of effective coils that are adjacently spaced apart to form a coil layer. As has been previously discussed with respect to the apparatus of the present invention, the coil layer comprises the plurality of effective coils such that the plurality of effective

coils may be energized to create magnetic fields wherein the magnetic fields at adjacent coil elements orient in opposite directions.

5       Next, at step 554, the method 550 includes generating an effective closed loop current in each of the plurality of effective coils to induce a magnetic field in each of the plurality of effective coils. The induced magnetic field thereby generates a surface treating plasma within the process chamber. Due to the localized magnetic field generation of the coil layer, the plasma is generated such that it is more localized and quieter than plasma generated by prior methods known in the art. From step 554, the method may proceed to steps 555, 556, or the end of the method depending upon the particular application.

10       At optional step 555, the method 550 includes inducing voltage differentials among the plurality of effective coils to generate electric fields. By inducing voltage differentials among the plurality of effective coils, charged particles will be directed in a non-perpendicular alignment by the coil layer. In this fashion, the plasma generated at the coil layer will be further quieted prior to its treatment of a substrate within the process chamber.

15       At step 556, the method 550 includes inducing voltage differentials among a plurality of coil layers or between coil layers and the process chamber. In this fashion, charged particles may be redirected within the process chamber.

20       Thus, the method 550 of FIG. 21 provides the important benefits of generating uniform quiet plasma within the process chamber without inducing large magnetic fields on the substrate within the process chamber or inducing magnetic fields outside of the process chamber that may affect sensors or that may magnetically couple to structures outside of the process chamber. Resultantly, the plasma within the process chamber 126 is uniform and quiet and will effectively treat the substrate contained within the plasma without damaging it and in uniformly treating the substrate.

25       FIG. 22 illustrates a method 600 for generating and filtering a surface treating plasma within a process chamber to produce a filtered plasma for the etching, ashing, and cleaning of a substrate and the deposition upon a substrate. The method commences at step 602 of generating a plasma within a first portion of the process chamber. The step of generating a plasma may include the generation of plasma with any particular device

30



or process step. Resultantly, the first portion of the process chamber may contain noisy plasma or may contain a quiet plasma if produced in accordance with the steps of the previously discussed method 550 of FIG. 21.

5       Next, at step 604, the method 600 includes operably connecting a plurality of coil elements within the process chamber to form a plurality of effective coils that are adjacently spaced apart to form a coil layer. At step 606, the method next includes generating an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils. The induced magnetic fields filter the plasma passing from the first portion of the process chamber to a second  
10       portion of the process chamber away from the first portion of the process chamber.

      Next, the method proceeds to step 608 of selectively biasing a plasma neutralizing grid with respect to the plurality of effective coils. The selective biasing causes plasma electrons and plasma ions to obtain substantially identical velocity so that at least a portion of the plasma electrons and plasma ions recombine to form neutralized particles that may  
15       be applied to treat the substrate within the process chamber.

      Thus, the method 600 of FIG. 22 provides the important benefit of generating, filtering, and neutralizing plasma so as to enable the treatment of substrates within a process chamber by neutralized particles having velocities approaching those of particles within a plasma. The application of the neutralized particles to the substrate performs the  
20       processes of etching, ashing, and deposition of substrates within a fabrication process step.

      The method 600 may also include the step of connecting a plurality of coil elements so as to allow the plasma to induce a current in the plurality of effective coils. As was previously discussed with respect to the structure of the present invention, when plasma is applied to a passively coil layer included operably connected coil elements, the plasma  
25       will induce currents in the effective coils so as to induce the magnetic fields in the effective coils. Resultantly, the plurality of coil elements will establish a filtering function within the process chamber. Alternatively, a source could be applied to the plurality of coil elements to produce the effective closed loop currents and accomplish the filtering function.

The method 600 could also include the step of accelerating plasma particles from the first portion of the process chamber to the second portion of the process chamber using a plasma accelerator/decelerator grid. Use of such a grid would be selectively used to accelerate and decelerate the charged plasma particles and to neutralize the particles so as to create energetic directional neutralized particles to treat semiconductive substrate within the process chamber.

The method of the present invention may also include coupling flat conductors 54 in a fashion previously described in conjunction with FIG. 10 to form plate elements. Coupling of flat conductors 54 in such a fashion forms a plurality of passages wherein the plurality of passages form a filtering region. The filtering region serves not only to filter the plasma particles but to neutralize the particles as has been previously discussed.

FIG. 23 illustrates a method of the present invention incorporating the various teachings of the present invention to create a neutralized particle stream within a process chamber for the etching and ashing and deposition of a substrate. The method 700 starts at step 702 wherein a plasma is generated within a process chamber. The plasma may be generated either with the coil layer structures described in accordance with the present invention or with a prior art plasma generation structure. In accordance with the method of the present invention, step 702 would either include the generation of a substantially quiet plasma via the coil layer generation structure of the present invention or noisy plasma through the use of a prior art generation structure.

From step 702 the method may proceed to step 704, 706 or step 708. Step 704 includes filtering the plasma generated in step 702 to generate a quiescent plasma within the process chamber. Step 704 has been previously described in conjunction with the method of FIG. 22 and the structure relating to the filtering of plasma.

From step 704 the method proceeds to step 706 which comprises selectively accelerating and decelerating plasma particles according to the characteristics of charge, energy, direction, and mass of the plasma particles. Preferably, the step is accomplished by applying time varying electric field within the process chamber using an acceleration/deceleration structure. Electric fields acting upon the charged particles cause the particles to accelerate or decelerate in a desired so that they obtain a substantially equal

velocity and recombine to form neutralized particles having substantially the same velocity as the ions. The application of electric fields has been previously discussed with respect to the apparatus of the present invention and will not be further described herein with respect to the method of the present invention. Some of the particles will likely not  
5 recombine but continue to move toward a substrate in the process chamber. Thus, after the execution of step 706, a particle stream comprised of both neutral and charged particles will be traveling toward the substrate.

From step 706, the method may proceed to step 708 or 710, depending upon the application in question. Step 708 includes removing charged particles through a charge  
10 filter contained within the process chamber. The charge filter may comprise a structure that has passages wherein the passages receive charged particles from the plasma as well as neutralized plasma particles. The charge filter alters the motion of charged particles moving towards a substrate in the process chamber as a particle stream. Thus, the charge filter may cause the charged particles to be removed from the passage or to recombine to  
15 form neutralized particles. Some charged particles are absorbed by a grid structure of the charge filter to remove the charged particles from the particle stream. Charged particles traveling in the process chamber may be deflected and collected by the application of a transverse electric generated by a parallel plate type grid filter and/or magnetic field in the process chamber. However, other structures such as the coil layer structure of the present  
20 invention with appropriate closed loop current generation could be used in conjunction with step 708 to remove the charged particles from the particle stream.

From step 708, the method proceeds to step 710 of applying the neutral particle stream in an etching, ashing, cleaning, or deposition process step. The application of the neutral particle stream will minimize the damage done to the substrate being processed in  
25 conjunction with the method 700.

Thus, the method 700 of the present invention may be selectively implemented in particular applications to achieve a particle tailored to a specific application. For example, all of the steps of the method 700 may be executed to achieve an optimized neutral stream. However, some of the steps may be bypassed in order to achieve differing stream qualities  
30 based upon the particular system processing requirements. Thus, the method 700 of FIG.

23 provides the flexibility needed to operate in various particular processing systems. Processes such as ashing, cleaning, deposition, and etching each require differing particle stream characteristics. Further, within particular categories, the particle stream must be customized to accomplish specific profiles, reactions, implantations, and particle removal rates. The method of the present invention may be tailored to generate particle streams to accomplish any of these process goals.

FIG. 24 illustrates a coil layer structure 1000 for operation at high frequencies in accordance with the present invention. Operational frequencies in the ultra high frequency (UHF) or microwave frequency range is accomplished. At these operating frequencies, current return paths are not required. Thus, the particular coil elements may be energized from a single end and operate like antennas. Connection structures 1002 operably connect the current drive element to the coil layer structure 1000 to generate the effective closed loop current 48 at each of the effective coils 47. In the structure shown, each connection structure 1002 provides current to two sections with each segment having two segments. Each of the segments comprises one-fourth of an effective coil 47. Since phasing of the current provided to the effective coils 47 is critical, each of the connection structures 1002 is balanced and properly distanced from the drive element so that the current in the coil elements 46 is properly phased.

The currents in the coil elements 46 provided by the connection structures 1002 and the drive element combine to create the effective closed loop currents 48. In this fashion, the effective closed loop currents 48 may be generated at high frequencies without providing a return path. The efficiency of the plasma generation process increases at higher generation frequencies. Thus, the structure of 1000 of FIG. 24 provides the important benefit of increased efficiency. Further, generation at higher frequencies generates lower temperature plasmas as compared to systems operating at lower frequencies. Lower temperature plasmas typically cause less damage to devices on substrates. Further, with the reduced hardware requirements of the structure 1000 of FIG. 24, the cost of the plasma generator is reduced.

FIG. 25 illustrates an alternative coil layer structure 1010 for operation at high frequencies. The structure of FIG. 25 is identical in construction and operation to the

structure of FIG. 24 except that each connection structure 1012 of the structure 1010 of FIG. 25 feeds only a single section having two segments with each segment forming one-fourth of an effective coil 47. Thus, the structure 1010 is even simpler in construction than the structure 1000 of FIG. 24 but provides the same important benefits. As opposed to the structure of FIG. 24 1000, the structure 1010 of FIG. 25 requires more connection structures 1012.

FIG. 26 illustrates another alternative coil layer structure 1020 for operation at high frequencies. The structure of FIG. 26 is identical in construction and operation to the structures of FIGs. 24 and 25 except that each connection structure 1022 of the structure 1020 of FIG. 26 feeds only a single segment that forms one-fourth of an effective coil 47. Thus, the structure 1020 is even simpler in construction than the structure 1010 of FIG. 25 but provides the same important benefits. As opposed to the structure of FIG. 25 1010, the structure 1020 of FIG. 26 requires more connection structures 1022.

FIG. 27 illustrates a coil layer structure 1030 for operation at high frequencies in accordance with the present invention similar in structure to the structures of FIGs. 24, 25, and 26 but wherein the effective coils 47 are substantially triangular in shape. Thus, the triangular effective coil structure 47 of FIG. 27 is similar to the effective coil 47 structure of FIG. 4f. As with the previous high frequency structures operating at frequencies in the ultra high frequency (UHF) or microwave frequency range is accomplished, current return paths are not required. Thus, the particular coil elements may be energized from a single end and operate like antennas. Connection structures 1032 operably connect the drive element to the coil layer structure 1030 to generate the effective closed loop current 48 at each of the effective coils 47. In the structure shown, each of the connection structures 1032 provides current having a common phase to three different segments 1036, each segment forming one-third of an effective coil 47 structure. In this fashion, the drive element supplies current consistently to each connection structure 1032. In this fashion, the structure of FIG. 27 provides the same important benefits provided by the structures of FIGs. 24 through 26 with a slightly similar construction.

FIG. 28 illustrates a coil layer structure 1040 for operation at high frequencies similar to the structure 1030 of FIG. 27. The structure of FIG. 28 is identical in

construction and operation to the structure of FIG. 27 except that each of a plurality of first connection structures 1042 connects to three positive-phase segments 1048 while each of a plurality of second connection structures 1044 connects to six segments, three positive-phase segments 1048 and three negative-phase segments 1050. Positive-phase segments 1048 and negative-phase segments 1050 propagate alternating currents 180 degrees out of phase with one another. The relative phase between the positive-phase current and the negative phase-current causes the effective closed loop current 48 to flow at each effective coil 47 and produce the magnetic fields the effective coils 47. Thus, the structure 1030 of FIG. 28 provides similar benefits as the structures of FIGs. 24 through 27 with a slightly different structure requiring fewer connection structures.

FIG. 29 illustrates an alternative coil layer structure 1050 having a substantially comb like structure forming the effective coils 47. In the structure 1050, a first plurality of substantially parallel conductors 1052 orient in a comb like structure connected on a first side and unconnected on a second side. On the first side, a connection structure 1054 couples the first plurality of parallel conductors 1052 to a drive element. A second plurality of substantially parallel conductors 1056 orient in a comb like structure connected on a first side and unconnected on a second side. The first plurality of parallel conductors 1052 and the second plurality of parallel conductors 1056 orient substantially parallel to one another but opposite one another. On the first side of the second plurality of substantially parallel conductors 1056, a connection structure 1058 couples the first plurality of parallel conductors 1052 to the drive element. Current drive provided to each of the conductors 1052 and 1056 is in phase so that the orientation of the conductors causes effective closed loop currents 48 to flow at each of the effective coils 47. Because of the relative elongation of the effective coils 47 and the end portions on the conductors that are perpendicular to their long axes, the end effects are negligible as compared to the adjacent currents extending in opposing directions. Thus, the application of a relatively high frequency, typically in the UHF or microwave range, the second ends of the conductors 1052 and 1056 need not be terminated to achieve the effective closed loop currents 48. Thus, the structure 1050 of FIG. 29 has a simple construction and yet provides the same benefits as have been previously described.

The above described preferred embodiments are intended to illustrate the principles of the invention, but not to limit the scope of the invention. Various other embodiments and modifications to these preferred embodiments may be made by those skilled in the art without departing from the scope of the following claims.

Claims:

1. An apparatus for generating a surface treating plasma within a process chamber, the apparatus comprising:

5 a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils that are adjacently spaced to form a coil layer; and

10 drive element, wherein the drive element operably couples to each of the plurality of coil elements, wherein the drive element generates an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils generate the surface treating plasma within the process chamber.

15 2. The apparatus of claim 1, wherein the drive element is selected from the group consisting of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, and combinational sources.

20 3. The apparatus of claim 1, wherein the drive element further comprises circuitry for inducing voltage differentials among the plurality of effective coils so as to create electric fields among the plurality of effective coils to direct charged plasma particles.

25 4. The apparatus of claim 1, wherein the plurality of operably connected coil elements comprise a plurality of conductors disposed within the process chamber.

5. The apparatus of claim 4, further comprising a coating disposed on the plurality of conductors.



6. The apparatus of claim 4, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes contain a circulating coolant.

5 7. The apparatus of claim 4, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes provide process gas to the process chamber.

10 8. The apparatus of claim 1, wherein the plurality of operably connected coil elements comprise a plurality of conductors disposed outside of the process chamber.

9. The apparatus of claim 8, further comprising:

15 containing housing, wherein the containing housing sealably attaches to an outer surface of the process chamber to form a housing volume, and wherein the housing volume contains the plurality of operably connected coil elements; and

20 dielectric liquid contained within the housing volume, wherein the dielectric liquid immerses the plurality of operably connected coil elements.

10. The apparatus of claim 1 further comprising biasing circuitry, wherein the biasing circuitry biases the plurality of operably connected coil elements at an average voltage level.

25 11. The apparatus of claim 1, wherein:

the plurality of operably connected coil elements further comprise:

30 a plurality of first conductors, wherein the plurality of first conductors orient substantially parallel to one another;

a plurality of second conductors, wherein the plurality of second conductors orient substantially parallel to one another, and wherein the plurality of second conductors are interwoven with the plurality of first conductors to form the coil layer; and

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the apparatus further comprises:

first drive element layer operably coupled to the drive element, wherein the first drive element layer orients substantially parallel to the coil layer, wherein the first drive element layer couples the drive element to the plurality of first conductors at first contact points, and wherein the first drive element layer couples the drive element to the second conductors at second contact points; and

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second drive element layer operably coupled to the drive element, wherein the second drive element layer orients substantially parallel to the coil layer, wherein the second drive element layer couples the drive element to the plurality of first conductors at third contact points, and wherein the second drive element layer couples the drive element to the second conductors at fourth contact points.

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12. The apparatus of claim 11, wherein at least some of the plurality of first conductors and plurality of second conductors comprise conductive pipes, wherein the conductive pipes contain a circulating coolant.

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13. The apparatus of claim 11, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes provide process gas to the process chamber.

14. The apparatus of claim 1, wherein the plurality of operably connected coil elements comprise a plurality of conductors disposed outside of the process chamber.
- 5 15. The apparatus of claim 1, wherein the plurality of operably connected coil elements comprise a plurality of substantially parallel conductors, wherein each of the plurality of substantially parallel conductors comprises a plurality of segments, and wherein segments of adjacent substantially parallel conductors form the plurality of effective coils.
- 10 16. The apparatus of claim 15, further comprising terminal connections among the plurality of substantially parallel conductors so as to cause current directions in adjacent conductors of the plurality of parallel conductors to be substantially opposite.
- 15 17. The apparatus of claim 15, wherein at least a portion of the plurality of substantially parallel conductors further comprise at least one looped segment, wherein each looped segment forms a closed loop at one of the effective coils.
- 20 18. The apparatus of claim 15, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise substantially perpendicularly oriented segments.
19. The apparatus of claim 15, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise curved segments.
- 25 20. The apparatus of claim 1, wherein each of the plurality of operably connected coil elements comprises a conductor segment, wherein each effective coil is formed by at least one conductor segment.

21. The apparatus of claim 20, wherein one conductor segment forms one of the effective coils.

22. The apparatus of claim 20, wherein at least two conductor segments form one of the effective coils.

23. The apparatus of claim 20, further comprising:

first drive element layer operably coupled to the drive element, wherein the first drive element layer operably couples the drive element to a first end of each of the conductor segments; and

second drive element layer operably coupled to the drive element, wherein the second drive element layer operably couples the drive element to a second end of each of the conductor segments.

24. The apparatus of claim 23, further comprising a plurality of shielded connections, wherein each shielded connection couples at least one conductor segment to a drive element layer.

25. The apparatus of claim 24, wherein shielded connections are selected from the group consisting of coaxial cables, triaxial cables, quadraxial cables, insulated wires, and twisted insulated wires.

26. The apparatus of claim 1, further comprising at least one plasma shielding element, wherein each plasma shielding element at least partially surrounds at least one of the coil elements to reduce a capacitive coupling between the plasma and a respective coil element.

27. The apparatus of claim 26, further comprising a plasma shielding connection element operably connected to at least one plasma shielding element, wherein the plasma shielding connection element is selected from the group consisting of direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, passive circuit elements, active circuit elements, and switches.

28. The apparatus of claim 1, wherein the plurality of operably connected coil elements comprise:

a first plurality of substantially parallel conductors conducting current in a first direction;

a second plurality of substantially parallel conductors disposed angularly with respect to the first plurality of substantially parallel conductors and conducting current in a second direction; and

a third plurality of substantially parallel conductors disposed angularly with respect to both the first plurality of substantially parallel conductors and the second plurality of substantially parallel conductors and conducting current in a third direction,

wherein each of the effective coils is formed by a portion of one of the first plurality of substantially parallel conductors, a portion of one of the second plurality of substantially parallel conductors, and a portion of one of the third plurality of substantially parallel conductors.

29. The apparatus of claim 28, wherein each of the plurality of effective coils comprises a substantially triangular shape.

30. The apparatus of claim 1, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially aligns with an axis of an adjacent effective coil.
- 5 31. The apparatus of claim 1, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially misaligns with an axis of an adjacent effective coil.
- 10 32. An apparatus for treating a substrate with a surface treating plasma, the apparatus comprising:
- a process chamber, wherein an inner portion of the process chamber may be isolated;
- 15 chuck disposed within the process chamber, wherein the chuck supports a substrate;
- gas injector, wherein the gas injector injects a treating gas within the process chamber;
- 20 a plurality of operably connected coil elements disposed within the process chamber, wherein the plurality of operably connected coil elements form a plurality of effective coils that are adjacently spaced to form a coil layer within the process chamber; and
- 25 drive element, wherein the drive element operably couples to each of the plurality of coil elements, wherein the drive element generates an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils to generate a plasma, and wherein magnetic fields induced at the plurality of effective coils produce a surface treating
- 30 plasma within the process chamber that bombards the substrate.

33. The apparatus of claim 32, further comprising:

a vacuum system, wherein the vacuum system creates a vacuum within the process chamber.

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34. The apparatus of claim 32, further comprising a plasma filter disposed within the process chamber between the coil layer and the chuck, wherein the plasma filter is substantially parallel to the coil layer, and wherein the plasma filter filters plasma passing from the coil layer to the chuck.

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35. The apparatus of claim 34, further comprising a plasma accelerator disposed within the process chamber between the coil layer and the chuck, wherein the plasma accelerator accelerates the plasma toward the chuck.

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36. The apparatus of claim 32, further comprising a plasma accelerator disposed within the process chamber between the coil layer and the chuck, wherein the plasma accelerator accelerates the plasma toward the chuck.

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37. The apparatus of claim 32, wherein the drive element is selected from the group consisting of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, and combinational sources.

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38. An apparatus for generating a surface treating plasma and for directing the surface treating plasma away from an inner surface of the process chamber, the apparatus comprising:

a plasma source that generates the surface treating plasma within the process chamber;

a plurality of operably connected coil elements disposed along a surface of the process chamber, wherein the plurality of operably connected coil elements form a plurality of effective coils that are adjacently spaced to form a coil layer adjacent a surface of the process chamber; and

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drive element, wherein the drive element operably couples to each of the plurality of coil elements, wherein the drive element generates an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils direct plasma particles generated within the process chamber away from the inner surface of the process chamber.

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39. The apparatus of claim 38, wherein the plasma source comprises:

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a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils that are adjacently spaced to form a coil layer; and

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second drive element, wherein the second drive element operably couples to each of the plurality of coil elements, wherein the second drive element generates an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils generate the surface treating plasma within the process chamber.

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40. The apparatus of claim 38, wherein the drive element is selected from the group consisting of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, and combinational sources.



41. The apparatus of claim 38, wherein the plurality of operably connected coil elements comprise conductors disposed along an inner surface of the process chamber.

5 42. The apparatus of claim 38, wherein the plurality of operably connected coil elements comprise conductors disposed along an outer surface of the process chamber.

10 43. A method for generating a surface treating plasma within a process chamber, the method comprising the steps of:

(a) operably connecting a plurality of coil elements within the process chamber to form a plurality of effective coils that are adjacently spaced to form a coil layer; and

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(b) generating an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, wherein magnetic fields induced at the plurality of effective coils generate the surface treating plasma within the process chamber.

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44. The method of claim 43, wherein the surface treating plasma is used in an etching process to etch a surface material selected from the group consisting of silicon, polysilicon, silicon dioxides, metals, silicides, silicon nitrides, dielectrics, polymers, and alloys.

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45. The method of claim 43, wherein the surface treating plasma is used in a deposition process wherein a material is deposited on a surface of the substrate, the material selected from the group consisting of silicon, polysilicon, silicon dioxides, metals, silicides, silicon nitrides, dielectrics, polymers, and alloys.

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46. The method of claim 43, wherein the surface treating plasma is used in an ashing process to ash and surface clean a surface material selected from the group consisting of photoresists, polymers, and residues.

5 47. The method of claim 43, further comprising the step of:

(c) inducing voltage differentials among the plurality of effective coils so as to create electric fields among the plurality of effective coils to direct charged plasma particles.

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48. A method for directing a surface treating plasma within a process chamber away from an inner surface of the process chamber, the method comprising the steps of:

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(a) operably connecting a plurality of coil elements along a surface of the process chamber to form a plurality of effective coils that are adjacently spaced to form a coil layer along a surface of the process chamber; and

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(b) generating an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, wherein magnetic fields induced at the plurality of effective coils directs plasma particles generated within the process chamber away from the inner surface of the process chamber.

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49. A plasma filtering apparatus for filtering plasma generated in a first portion of a process chamber by a plasma source to produce a filtered plasma in a second portion of the process chamber away from the first portion of the process chamber, the apparatus comprising:

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a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils disposed within the

process chamber, wherein the plurality of effective coils are adjacently spaced to form a coil layer separating the first portion of the process chamber from the second portion of the process chamber, wherein an effective closed loop current at each of the plurality of effective coils induces a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils filter the plasma.

50. The apparatus of claim 49, further comprising:
- at least one passive connection between the plurality of operably connected coil elements, wherein the passive connection allows the plasma to produce a current in the plurality of effective coils to induce a magnetic field at each of the plurality of effective coils.
51. The apparatus of claim 49, further comprising:
- at least one passive connection between the plurality of operably connected coil elements and the process chamber, wherein the passive connection allows the plasma to produce a current in the plurality of effective coils to induce a magnetic field at each of the plurality of effective coils.
52. The apparatus of claim 49, wherein the plurality of operably connected coil elements comprise a plurality of conductors disposed within the process chamber.
53. The apparatus of claim 52, wherein the plurality of conductors further comprise a protective coating.
54. The apparatus of claim 52, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes contain a circulating coolant.

55. The apparatus of claim 52, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes provide process gas to the process chamber.
- 5 56. The apparatus of claim 49 further comprising biasing circuitry, wherein the biasing circuitry biases the plurality of operably connected coil elements at a bias voltage level.
- 10 57. The apparatus of claim 49, wherein the plurality of operably connected coil elements further comprise:
- a plurality of first conductors, wherein the plurality of first conductors orient substantially parallel to one another; and
- 15 a plurality of second conductors, wherein the plurality of second conductors orient substantially parallel to one another, and wherein the plurality of second conductors are interwoven with the plurality of first conductors to form the coil layer.
- 20 58. The apparatus of claim 49, wherein the plurality of operably connected coil elements comprise a plurality of substantially parallel conductors, wherein each of the plurality of substantially parallel conductors comprises a plurality of segments, and wherein segments of adjacent substantially parallel conductors form the plurality of effective coils.
- 25 59. The apparatus of claim 58, further comprising terminal connections among the plurality of substantially parallel conductors so as to cause current directions in adjacent conductors of the plurality of parallel conductors to be substantially opposite.

60. The apparatus of claim 58, wherein at least a portion of the plurality of substantially parallel conductors further comprise at least one looped segment, wherein each looped segment forms a closed loop at one of the effective coils.

5 61. The apparatus of claim 58, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise substantially perpendicularly oriented segments.

62. The apparatus of claim 58, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise curved segments.

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63. The apparatus of claim 49, wherein each of the plurality of operably connected coil elements comprises a conductor segment, wherein each effective coil is formed by at least one conductor segment.

15 64. The apparatus of claim 63, wherein one conductor segment forms one of the effective coils.

65. The apparatus of claim 63, wherein at least two conductor segments form one of the effective coils.

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66. The apparatus of claim 63, further comprising:

first conductive layer operably coupling to a first end of each of the conductor segments; and

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second conductive layer operably coupling to a second end of each of the conductor segments.

67. The apparatus of claim 66, further comprising a plurality of shielded connections, wherein each shielded connection couples at least one conductor segment to a element layer.
- 5 68. The apparatus of claim 67, wherein shielded connections are selected from the group consisting of coaxial cables, triaxial cables, quadraxial cables, insulated wires, and twisted insulated wires.
- 10 69. The apparatus of claim 49, further comprising at least one plasma shielding element, wherein each plasma shielding element at least partially surrounds at least one of the coil elements to reduce a capacitive coupling between the plasma and a respective coil element.
- 15 70. The apparatus of claim 69, further comprising a plasma shielding connection operably connected to at least one plasma shielding element, wherein the plasma shielding connection is selected from the group consisting of direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, passive circuit elements, active circuit elements, and switches.
- 20 71. The apparatus of claim 49, wherein the plurality of operably connected coil elements comprise:
- 25 a first plurality of substantially parallel conductors conducting current in a first direction;
- a second plurality of substantially parallel conductors disposed angularly with respect to the first plurality of substantially parallel conductors and conducting current in a second direction; and

a third plurality of substantially parallel conductors disposed angularly with respect to both the first plurality of substantially parallel conductors and the second plurality of substantially parallel conductors and conducting current in a third direction,

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wherein each of the effective coils is formed by a portion of one of the first plurality of substantially parallel conductors, a portion of one of the second plurality of substantially parallel conductors, and a portion of one of the third plurality of substantially parallel conductors.

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72. The apparatus of claim 71, wherein each of the plurality of effective coils comprises a substantially triangular shape.

73. The apparatus of claim 49, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially aligns with an axis of an adjacent effective coil.

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74. The apparatus of claim 49, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially misaligns with an axis of an adjacent effective coil.

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75. A plasma filtering apparatus for filtering plasma generated in a first portion of a process chamber by a plasma source to produce a filtered plasma in a second portion of the process chamber away from the first portion of the process chamber, the apparatus comprising:

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a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils disposed within the process chamber, wherein the plurality of effective coils are adjacently spaced to

form a coil layer separating the first portion of the process chamber from the second portion of the process chamber; and

5 a drive element operably coupled to the plurality of operably connected coil elements, wherein the drive element generates an effective closed loop current at each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils filter the plasma passing to the second portion of the process chamber.

10 76. The apparatus of claim 75, wherein:

the plurality of operably connected coil elements further comprise:

15 a plurality of first conductors, wherein the plurality of first conductors orient substantially parallel to one another;

a plurality of second conductors, wherein the plurality of second conductors orient substantially parallel to one another, and wherein the plurality of  
20 second conductors are interwoven with the plurality of first conductors to form the coil layer; and

the apparatus further comprises:

25 first drive element layer operably coupled to the drive element, wherein the first drive element layer orients substantially parallel to the coil layer, wherein the first drive element layer couples the drive element to the plurality of first conductors at first contact points, and wherein the first drive element layer couples the drive element to the second conductors at  
30 second contact points; and



second drive element layer operably coupled to the drive element, wherein the second drive element layer orients substantially parallel to the coil layer, wherein the second drive element layer couples the drive element to the plurality of first conductors at third contact points, and wherein the second drive element layer couples the drive element to the second conductors at fourth contact points.

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77. The apparatus of claim 76, wherein at least some of the plurality of first conductors and plurality of second conductors comprise conductive pipes, wherein the conductive pipes contain a circulating coolant.
78. The apparatus of claim 76, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes provide process gas to the process chamber.
79. The apparatus of claim 75, further comprising selectively controllable biasing circuitry operably coupled to the plasma filter for biasing the plasma filter with respect to the plasma for accelerating and decelerating the plasma passing through the plasma filter.
80. The apparatus of claim 75, further comprising an accelerator/decelerator grid disposed in the second portion of the process chamber, wherein the accelerator/decelerator grid is selectively biased with respect to the plasma filter, wherein selective biasing of the accelerator/decelerator grid accelerates and decelerates the plasma passing through the plasma filter.
81. The apparatus of claim 75, further comprising an accelerator/decelerator grid disposed in the first portion of the process chamber, wherein the accelerator/decelerator grid is selectively biased with respect to the plasma filter,

wherein selective biasing of the accelerator/decelerator grid accelerates and decelerates the plasma passing through the plasma filter.

- 5      82.      The apparatus of claim 75, further comprising selectively controllable biasing circuitry operably coupled to the plasma filter and a chuck disposed within the second portion of the process chamber, the chuck for holding a substrate, where the biasing circuitry selectively biases the chuck with respect to the plasma filter for accelerating and decelerating the plasma passing through the plasma filter.
- 10      83.      The apparatus of claim 75, wherein the plurality of operably connected coil elements comprise a plurality of substantially parallel conductors, wherein each of the plurality of substantially parallel conductors comprises a plurality of segments, and wherein segments of adjacent substantially parallel conductors form the plurality of effective coils.
- 15      84.      The apparatus of claim 83, further comprising terminal connections among the plurality of substantially parallel conductors so as to cause current directions in adjacent conductors of the plurality of parallel conductors to be substantially opposite.
- 20      85.      The apparatus of claim 83, wherein at least a portion of the plurality of substantially parallel conductors further comprise at least one looped segment, wherein each looped segment forms a closed loop at one of the effective coils.
- 25      86.      The apparatus of claim 83, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise substantially perpendicularly oriented segments.
- 30      87.      The apparatus of claim 83, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise curved segments.

5 88. The apparatus of claim 75, wherein the drive element is selected from the group consisting of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, combinational direct voltage and alternating current sources, passive circuit elements, active circuit elements, and switches.

10 89. The apparatus of claim 75, further comprising  
second plasma filter, wherein the second plasma filter filters plasma passing from the first portion of the process chamber to a second portion of the process chamber away from the first portion of the process chamber, wherein the second plasma filter includes:

15 second plurality of operably connected coil elements disposed within the process chamber, wherein the second plurality of operably connected coil elements form a second plurality of effective coils disposed within the process chamber, wherein the second plurality of effective coils are adjacently spaced to form a second coil layer disposed substantially parallel to the plasma filter within the process chamber; and

20 second drive element operably coupled to the second plurality of coil elements, wherein the second drive element produces a current in the plurality of second coil elements to induce a magnetic field at each of the second plurality of effective coils, and wherein magnetic fields induced at  
25 the second plurality of effective coils filters the plasma.

90. The apparatus of claim 89, wherein the second drive element is selected from the group consisting of at least of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, combinational direct

voltage and alternating current sources, passive circuit elements, active circuit elements, and switches.

- 5 91. The apparatus of claim 89, further comprising a conductive grid disposed substantially parallel to and adjacent the coil layer.
- 10 92. The apparatus of claim 91, further comprising grid biasing circuitry, wherein the grid biasing circuitry biases a voltage of the conductive grid with respect to the plasma filter.
- 15 93. The apparatus of claim 91, further comprising at least one passive connection between the conductive grid and the process chamber.
94. The apparatus of claim 91, further comprising at least one active connection between the conductive grid and the process chamber.
- 20 95. The apparatus of claim 75, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially aligns with an axis of an adjacent effective coil.
96. The apparatus of claim 75, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially misaligns with an axis of an adjacent effective coil.
- 25 97. The apparatus of claim 75, wherein each of the plurality of operably connected coil elements comprises a conductor segment, wherein each effective coil is formed by at least one conductor segment.
- 30 98. The apparatus of claim 97, wherein one conductor segment forms one of the effective coils.

99. The apparatus of claim 97, wherein at least two conductor segments form one of the effective coils.

100. The apparatus of claim 97, further comprising:

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first drive element layer operably coupled to the drive element, wherein the first drive element layer operably couples the drive element to a first end of each of the conductor segments; and

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second drive element layer operably coupled to the drive element, wherein the second drive element layer operably couples the drive element to a second end of each of the conductor segments.

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101. The apparatus of claim 100, further comprising a plurality of shielded connections, wherein each shielded connection couples at least one conductor segment to a drive element layer.

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102. The apparatus of claim 101, wherein shielded connections are selected from the group consisting of coaxial cables, triaxial cables, quadraxial cables, insulated wires, and twisted insulated wires.

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103. The apparatus of claim 75, wherein the plurality of operably connected coil elements comprise:

a first plurality of substantially parallel conductors conducting current in a first direction;

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a second plurality of substantially parallel conductors disposed angularly with respect to the first plurality of substantially parallel conductors and conducting current in a second direction; and

a third plurality of substantially parallel conductors disposed angularly with respect to both the first plurality of substantially parallel conductors and the second plurality of substantially parallel conductors and conducting current in a third direction,

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wherein each of the effective coils is formed by a portion of one of the first plurality of substantially parallel conductors, a portion of one of the second plurality of substantially parallel conductors, and a portion of one of the third plurality of substantially parallel conductors.

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104. The apparatus of claim 103, wherein each of the plurality of effective coils comprises a substantially triangular shape.

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105. The apparatus of claim 75, further comprising at least one plasma shielding element, wherein each plasma shielding element at least partially surrounds at least one of the coil elements to reduce a capacitive coupling between the plasma and a respective coil element.

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106. The apparatus of claim 105, further comprising a plasma shielding connection element operably connected to at least one plasma shielding element, wherein the plasma shielding connection element is selected from the group consisting of direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, passive circuit elements, active circuit elements, and switches.

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107. A plasma filter and accelerator/decelerator for filtering and accelerating plasma particles passing from a first portion of a process chamber to a second portion of the process chamber, the apparatus comprising:

plasma filter, wherein the plasma filter filters plasma passing from the first portion of the process chamber to a second portion of the process chamber away from the first portion of the process chamber, wherein the plasma filter comprises:

5           a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils disposed within the process chamber, wherein the plurality of effective coils are adjacently spaced to form a coil layer separating the first portion of the process chamber from the second portion of the process chamber;

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a drive element operably coupled to the plurality of operably connected coil elements, wherein the drive element generates an effective closed loop current at each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields  
15           induced at the plurality of effective coils filter the plasma; and

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plasma accelerator/decelerator grid disposed substantially parallel to and adjacent the coil layer, wherein the plasma accelerator/decelerator grid is biased with respect to the plasma filter such that the plasma accelerator/decelerator grid along  
20           with the plasma filter causes plasma particles to accelerate from the first portion of the process chamber to the second portion of the process chamber.

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108. The apparatus of claim 107, further comprising biasing circuitry, wherein the biasing circuitry biases the plasma accelerator/decelerator grid with respect to the  
25           plasma filter.

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109. The apparatus of claim 109, wherein the biasing circuitry is selected from the group consisting of direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, passive circuit elements, active circuit  
30           elements, and switches.

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110. The apparatus of claim 107, wherein the plasma accelerator/decelerator grid comprises:

5 second plurality of operably connected coil elements disposed within the process chamber, wherein the second plurality of operably connected coil elements form a second plurality of effective coils disposed within the process chamber, wherein the second plurality of effective coils are adjacently spaced to form a second coil layer disposed substantially parallel to the plasma filter within the process chamber; and

10 second drive element operably coupled to the second plurality of coil elements, wherein the second drive element produces a current in the plurality of second coil elements to induce a magnetic field at each of the second plurality of effective coils, and wherein magnetic fields induced at the second plurality of effective coils  
15 filters the plasma.

111. An apparatus for directing plasma away from an inner surface of a process chamber, the apparatus comprising:

20 a plurality of operably connected coil elements disposed along a surface of the process chamber, wherein the plurality of operably connected coil elements form a plurality of effective coils that are spaced adjacently in two dimensions to form a coil layer adjacent the surface of the process chamber; and

25 drive element, wherein the drive element operably couples to each of the plurality of coil elements, wherein the drive element generates an effective closed loop current in each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils directs plasma particles generated within the process  
30 chamber away from the inner surface of the process chamber.



112. The apparatus of claim 111, wherein the plurality of operably connected coil elements comprise conductors disposed along an inner surface of the process chamber.
- 5 113. The apparatus of claim 111, wherein the plurality of operably connected coil elements comprise conductors disposed along an outer surface of the process chamber.
- 10 114. A method for producing a uniform surface treating plasma within a process chamber to produce a filtered plasma, the method comprising the steps of:
- (a) generating a plasma within a first portion of the process chamber; and
  - 15 (b) operably connecting a plurality of coil elements within the process chamber to form a plurality of effective coils that are adjacently spaced to form a coil layer, wherein the coil layer separates the first portion of the process chamber from a second portion of the process chamber away from the first portion of the process chamber; and
  - 20 (c) generating an effective closed loop current in each of the plurality of coil elements so as to induce a magnetic field at each of the plurality of effective coils to thereby filter plasma passing from the first portion of the process chamber to the second portion of the process chamber.
- 25 115. The method of claim 114, wherein step (c) includes operably coupling the plurality of coil elements so as to allow the plasma to induce a current in the plurality of effective coils.

116. The method of claim 114, wherein step (c) includes operably coupling a drive element to the plurality of coil elements so as to generate an effective closed loop current at each of the plurality of effective coils.
- 5 117. The method of claim 114, further comprising the step of:
- (d) accelerating plasma particles from the first portion of the process chamber to the second portion of the process chamber using a plasma accelerator/decelerator grid disposed substantially parallel to and adjacent  
10 the coil layer, wherein the plasma accelerator/decelerator grid is biased with respect to the plasma filter.
118. The method of claim 114, wherein step (b) includes orientating the operably connected coil elements such that at least one effective coil has an axis that  
15 substantially aligns with an axis of an adjacent effective coil.
119. The method of claim 114, wherein step (b) includes orientating the operably connected coil elements such that at least one effective coil has an axis that  
20 substantially misaligns with an axis of an adjacent effective coil.
120. The method of claim 114, wherein the surface treating plasma is used in an etching process to etch a surface material selected from the group consisting of silicon, polysilicon, silicon dioxides, metals, silicides, silicon nitrides, dielectrics, polymers, and alloys.  
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121. The method of claim 114, wherein the surface treating plasma is used in a deposition process wherein a material is deposited on a surface of the substrate, the material selected from the group consisting of silicon, polysilicon, silicon dioxides, metals, silicides, silicon nitrides, dielectrics, polymers, and alloys.  
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122. The method of claim 114, wherein the surface treating plasma is used in an ashing process to ash and surface clean a surface material selected from the group consisting of photoresists, polymers, and residues.

5 123. An apparatus for filtering and neutralizing plasma particles within a process chamber, the apparatus comprising:

plasma filter disposed within the process chamber, wherein the plasma filter filters plasma passing from a first portion of the process chamber to a second portion of  
10 the process chamber away from the first portion of the process chamber, wherein the plasma filter includes:

a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils disposed  
15 within the process chamber, wherein the plurality of effective coils are adjacently spaced to form a coil layer separating the first portion of the process chamber from the second portion of the process chamber;

a drive element operably coupled to the plurality of operably connected coil  
20 elements, wherein the drive element generates an effective closed loop current at each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils filter the plasma;

25 plasma neutralizing grid disposed substantially parallel to and adjacent the coil layer; and

plasma neutralizing circuitry, wherein the plasma neutralizing circuitry selectively  
biases the plasma neutralizing grid with respect to the plasma filter such that the  
30 plasma neutralizing grid along with the plasma filter causes plasma electrons and

plasma ions to obtain a substantially identical velocity so that at least a portion of the plasma electrons and plasma ions recombine to form neutralized particles.

5 124. The apparatus of claim 123 wherein the drive element is selected from the group consisting of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, combinational direct voltage and alternating current sources, passive circuit elements, active circuit elements, and switches.

10 125. The apparatus of claim 123, wherein the plasma neutralizing grid comprises a conductive mesh.

15 126. The apparatus of claim 123, wherein the plasma neutralizing circuitry further comprises control circuitry for causing substantial recombination of the plasma electrons and plasma ions between the plasma filter and the plasma neutralizing grid.

20 127. The apparatus of claim 123, wherein the plasma neutralizing circuitry further comprises control circuitry for causing substantial recombination of the plasma electrons and plasma ions on a side of the plasma neutralizing grid opposite the plasma filter.

25 128. The apparatus of claim 123, wherein the drive element further comprises circuitry for inducing voltage differences among the plurality of effective coil elements so as to create electric fields among the plurality of effective coils to direct charge plasma particles.

30 129. The apparatus of claim 123, wherein the plurality of operably connected coil elements comprise a plurality of conductors.

130. The apparatus of claim 129, wherein the plurality of conductors further comprise a protective coating.

5 131. The apparatus of claim 129, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes contain a circulating coolant.

10 132. The apparatus of claim 129, wherein at least some of the plurality of conductors comprise conductive pipes, wherein the conductive pipes provide process gas to the process chamber.

133. The apparatus of claim 123, wherein:

the plurality of operably connected coil elements comprise:

15 a plurality of first conductors, wherein the plurality of first conductors orient substantially parallel to one another;

20 a plurality of second conductors, wherein the plurality of second conductors orient substantially parallel to one another, and wherein the plurality of second conductors are interwoven with the plurality of first conductors to form the coil layer; and

the apparatus further comprises:

25 first drive element layer operably coupled to the drive element, wherein the first drive element layer orients substantially parallel to the coil layer, wherein the first drive element layer couples the drive element to the plurality of first conductors at first contact points, and wherein the first

drive element layer couples the drive element to the second conductors at second contact points; and

second drive element layer operably coupled to the drive element, wherein the second drive element layer orients substantially parallel to the coil layer, wherein the second drive element layer couples the drive element to the plurality of first conductors at third contact points, and wherein the second drive element layer couples the drive element to the second conductors at fourth contact points.

134. The apparatus of claim 123, wherein the plurality of operably connected coil elements comprise a plurality of substantially parallel conductors, wherein each of the plurality of substantially parallel conductors comprises a plurality of segments, and wherein segments of adjacent substantially parallel conductors form the plurality of effective coils.

135. The apparatus of claim 134, further comprising terminal connections among the plurality of substantially parallel conductors so as to cause current directions in adjacent conductors of the plurality of parallel conductors to be substantially opposite.

136. The apparatus of claim 134, wherein at least a portion of the plurality of substantially parallel conductors further comprise at least one looped segment, wherein each looped segment forms a closed loop at one of the effective coils.

137. The apparatus of claim 134, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise substantially perpendicularly oriented segments.

138. The apparatus of claim 134, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise curved segments.

139. The apparatus of claim 123, wherein the plasma neutralizing grid comprises:

5

a second plurality of operably connected coil elements disposed within the process chamber, wherein the second plurality of operably connected coil elements form a second plurality of effective coils disposed within the process chamber, wherein the plurality of effective coils are adjacently spaced to form a second coil layer disposed substantially parallel to the coil layer of the plasma filter.

10

140. The apparatus of claim 139, further comprising:

15

second drive element operably coupled to the second plurality of coil elements, wherein the second drive element produces a current in the second plurality of coil elements to induce a magnetic field at each of the second plurality of effective coils, and wherein magnetic fields induced at the second plurality of effective coils filter the plasma.

20

141. The apparatus of claim 140 wherein the second drive element is selected from the group consisting of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, combinational direct voltage and alternating current sources, passive circuit elements, active circuit elements, and switches.

25

142. The apparatus of claim 139, further comprising:

at least one passive connection between the second plurality of operably connected coil elements, wherein the passive connection allows the plasma to produce a current in the second plurality of effective coils to induce a magnetic field at each

30

of the second plurality of effective coils, wherein magnetic fields induced at the second plurality of effective coils filter the plasma.

- 5 143. The apparatus of claim 139, wherein the second drive element further comprises circuitry for inducing voltage differences among the plurality of effective coil elements so as to create electric fields among the plurality of effective coils to direct charged plasma particles.
- 10 144. The apparatus of claim 123, further comprising biasing circuitry operably coupled to the plasma filter for biasing the plasma filter with respect to the plasma for accelerating and decelerating the plasma passing through the plasma filter.
- 15 145. The apparatus of claim 123, further comprising an accelerator/decelerator grid disposed in the second portion of the process chamber, wherein the accelerator/decelerator grid is selectively biased with respect to the plasma filter, and wherein selective biasing of the accelerator/decelerator grid accelerates and decelerates the plasma passing through the plasma filter.
- 20 146. The apparatus of claim 123, further comprising an accelerator/decelerator grid disposed in the first portion of the process chamber, wherein the accelerator/decelerator grid is selectively biased with respect to the plasma filter, and wherein selective biasing of the accelerator/decelerator grid accelerates and decelerates the plasma passing through the plasma filter.
- 25 147. The apparatus of claim 123, further comprising selectively controllable biasing circuitry operably connected between the plasma filter and a chuck disposed within the second portion of the process chamber, the chuck for holding a substrate, wherein the biasing circuitry selectively biases the chuck with respect to the plasma filter to accelerate and decelerate the plasma passing through the plasma filter.



148. The apparatus of claim 123, wherein the plurality of operably connected coil elements orient such that at least one effective coil has an axis that substantially aligns with an axis of an adjacent effective coil.

5 149. The apparatus of claim 123, wherein the plurality of operably connected coil elements orient such that at least one effective coil has an axis that substantially misaligns with an axis of an adjacent effective coil.

10 150. The apparatus of claim 123, wherein each of the plurality of operably connected coil elements comprises a conductor segment, wherein each effective coil is formed by at least one conductor segment.

151. The apparatus of claim 150, wherein one conductor segment forms one of the effective coils.

15 152. The apparatus of claim 151, wherein at least two conductor segments form one of the effective coils.

20 153. The apparatus of claim 150, further comprising:  
  
first drive element layer operably coupled to the drive element, wherein the first drive element layer operably couples the drive element to a first end of each of the conductor segments; and

25 second drive element layer operably coupled to the drive element, wherein the second drive element layer operably couples the drive element to a second end of each of the conductor segments.

154. The apparatus of claim 153, further comprising a plurality of shielded connections, wherein each shielded connection couples at least one conductor segment to a drive element layer.

5 155. The apparatus of claim 154, wherein shielded connections are selected from the group consisting of coaxial cables, triaxial cables, quadraxial cables, insulated wires, and twisted insulated wires.

10 156. The apparatus of claim 123, wherein the plurality of operably connected coil elements comprise:

a first plurality of substantially parallel conductors conducting current in a first direction;

15 a second plurality of substantially parallel conductors disposed angularly with respect to the first plurality of substantially parallel conductors and conducting current in a second direction; and

20 a third plurality of substantially parallel conductors disposed angularly with respect to both the first plurality of substantially parallel conductors and the second plurality of substantially parallel conductors and conducting current in a third direction,

25 wherein each of the effective coils is formed by a portion of one of the first plurality of substantially parallel conductors, a portion of one of the second plurality of substantially parallel conductors, and a portion of one of the third plurality of substantially parallel conductors.

30 157. The apparatus of claim 156, wherein each of the plurality of effective coils comprises a substantially triangular shape.

158. The apparatus of claim 123, further comprising at least one plasma shielding element, wherein each plasma shielding element at least partially surrounds at least one of the coil elements to reduce a capacitive coupling between the plasma and a respective coil element.

5

159. The apparatus of claim 158, further comprising a plasma shielding connection element operably connected to at least one plasma shielding element, wherein the plasma shielding connection element is selected from the group consisting of direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, passive circuit elements, active circuit elements, and switches.

10

160. An apparatus for filtering and neutralizing plasma particles within a process chamber, the apparatus comprising:

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plasma filter disposed within the process chamber, wherein the plasma filter filters plasma passing from a first portion of the process chamber to a second portion of the process chamber away from the first portion of the process chamber, wherein the plasma filter includes:

20

a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils disposed within the process chamber, wherein the plurality of effective coils are adjacently spaced to form a coil layer separating the first portion of the process chamber from the second portion of the process chamber;

25

a drive element operably coupled to the plurality of operably connected coil elements, wherein the drive element generates an effective closed loop current at each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils filter the plasma; and

30

plasma neutralizing circuitry, wherein the plasma neutralizing circuitry selectively biases the plurality of operably connected coil elements with respect to the plasma within the process chamber to accelerate and decelerate plasma electrons and ions to causes the plasma electrons and plasma ions to obtain a substantially identical velocity so that at least a portion of the plasma electrons and plasma ions recombine to form neutralized particles.

161. The apparatus of claim 160 wherein the drive element is selected from the group consisting of at least direct current sources, direct voltage sources, alternating current sources, alternating voltage sources, combinational direct voltage and alternating current sources, passive circuit elements, active circuit elements, and switches.

162. The apparatus of claim 160, wherein the plasma neutralizing circuitry further comprises control circuitry for causing substantial recombination of the plasma electrons and plasma ions in the first portion of the process chamber.

163. The apparatus of claim 160, wherein the plasma neutralizing circuitry further comprises control circuitry for causing substantial recombination of the plasma electrons and plasma ions in the second portion of the process chamber.

164. The apparatus of claim 160, wherein the drive element further comprises circuitry for inducing voltage differences among the plurality of effective coil elements so as to create electric fields among the plurality of effective coils to direct charged plasma particles.

165. The apparatus of claim 160, wherein the plurality of operably connected coil elements comprise:

a plurality of first conductors, wherein the plurality of first conductors orient substantially parallel to one another;

a plurality of second conductors, wherein the plurality of second conductors orient substantially parallel to one another, and wherein the plurality of second conductors are interwoven with the plurality of first conductors to form the coil layer; and

the apparatus further comprises:

first drive element layer operably coupled to the drive element, wherein the first drive element layer orients substantially parallel to the coil layer, wherein the first drive element layer couples the drive element to the plurality of first conductors at first contact points, and wherein the first drive element layer couples the drive element to the second conductors at second contact points; and

second drive element layer operably coupled to the drive element, wherein the second drive element layer orients substantially parallel to the coil layer, wherein the second drive element layer couples the drive element to the plurality of first conductors at third contact points, and wherein the second drive element layer couples the drive element to the second conductors at fourth contact points.

166. The apparatus of claim 160, wherein the plurality of operably connected coil elements comprise a plurality of substantially parallel conductors, wherein each of the plurality of substantially parallel conductors comprises a plurality of segments, and wherein segments of adjacent substantially parallel conductors form the plurality of effective coils.

- 5 167. The apparatus of claim 166, further comprising terminal connections among the plurality of substantially parallel conductors so as to cause current directions in adjacent conductors of the plurality of parallel conductors to be substantially opposite.
168. The apparatus of claim 166, wherein at least a portion of the plurality of substantially parallel conductors further comprise at least one looped segment, wherein each looped segment forms a closed loop at one of the effective coils.
- 10 169. The apparatus of claim 166, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise substantially perpendicularly oriented segments.
- 15 170. The apparatus of claim 166, wherein adjacent segments of the plurality of segments of the substantially parallel conductors comprise curved segments.
- 20 171. The apparatus of claim 160, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially aligns with an axis of an adjacent effective coil.
- 25 172. The apparatus of claim 160, wherein the plurality of operably connected coil elements have orientations such that at least one effective coil has an axis that substantially misaligns with an axis of an adjacent effective coil.
- 30 173. The apparatus of claim 160, wherein each of the plurality of operably connected coil elements comprises a conductor segment, wherein each effective coil is formed by at least one conductor segment.
174. The apparatus of claim 173, wherein one conductor segment forms one of the effective coils.

175. The apparatus of claim 173, wherein at least two conductor segments form one of the effective coils.

176. The apparatus of claim 173, further comprising:

5

first drive element layer operably coupled to the drive element, wherein the first drive element layer operably couples the drive element to a first end of each of the conductor segments; and

10

second drive element layer operably coupled to the drive element, wherein the second drive element layer operably couples the drive element to a second end of each of the conductor segments.

15

177. The apparatus of claim 176, further comprising a plurality of shielded connections, wherein each shielded connection couples at least one conductor segment to a drive element layer.

20

178. The apparatus of claim 177, wherein shielded connections are selected from the group consisting of coaxial cables, triaxial cables, quadraxial cables, insulated wires, and twisted insulated wires.

25

179. The apparatus of claim 160, wherein the plurality of operably connected coil elements comprise:

a first plurality of substantially parallel conductors conducting current in a first direction;

30

a second plurality of substantially parallel conductors disposed angularly with respect to the first plurality of substantially parallel conductors and conducting current in a second direction; and

a third plurality of substantially parallel conductors disposed angularly with respect to both the first plurality of substantially parallel conductors and the second plurality of substantially parallel conductors and conducting current in a third direction,

5

wherein each of the effective coils is formed by a portion of one of the first plurality of substantially parallel conductors, a portion of one of the second plurality of substantially parallel conductors, and a portion of one of the third plurality of substantially parallel conductors.

10

180. The apparatus of claim 179, wherein each of the plurality of effective coils comprises a substantially triangular shape.

181. The apparatus of claim 160, further comprising at least one plasma shielding element, wherein each plasma shielding element at least partially surrounds at least one of the coil elements to reduce a capacitive coupling between the plasma and a respective coil element.

15

182. The apparatus of claim 181, further comprising a plasma shielding connection element operably connected to at least one plasma shielding element, wherein the plasma shielding connection element is selected from the group consisting of direct voltage sources, alternating voltage sources, direct current sources, alternating current sources, passive circuit elements, active circuit elements, and switches.

20

183. An apparatus for filtering and neutralizing plasma particles within a process chamber, the apparatus comprising:

25

plasma filter disposed within the process chamber, wherein the plasma filter filters plasma passing from a first portion of the process chamber to a second portion of the process chamber away from the first portion of the process chamber;

30



plasma neutralizing grid disposed substantially parallel to and adjacent the coil layer, wherein the plasma filter includes:

5 a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils disposed within the process chamber, wherein the plurality of effective coils are adjacently spaced to form a coil layer separating the first portion of the process chamber from the second portion of the process chamber;

10 a drive element operably coupled to the plurality of operably connected coil elements, wherein the drive element generates an effective closed loop current at each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils filter the plasma; and

15 plasma neutralizing circuitry, wherein the plasma neutralizing circuitry selectively biases the plasma neutralizing grid with respect to the plasma filter such that the plasma neutralizing grid along with the plasma filter causes plasma electrons and plasma ions to obtain a substantially identical velocity so that at least a portion of  
20 the plasma electrons and plasma ions recombine to form neutralized particles.

184. An apparatus for filtering and neutralizing a plasma within a process chamber, the apparatus comprising:

25 a plurality of operably connected plate elements disposed within the process chamber, wherein the plurality of plate elements are adjacently spaced to form a plurality of passages, and wherein the plurality of passages form a filtering region; and

drive element operably coupling the plurality of plate elements, wherein the drive element produces a current in the plurality of plate elements to induce a magnetic field in each of the plurality of passages, wherein a magnetic field in each passage orients substantially parallel to a longitudinal direction of the passage such that positive ions and electrons of the plasma are directed by the magnetic field to filter and neutralize the plasma.

185. The apparatus of claim 184, further comprising:

biasing drive element operably coupled to the plurality of plate elements, wherein the biasing drive element biases the plurality of plate elements to induce an electric field in each of the plurality of passages, wherein the electric field in each passage orients substantially perpendicular to the longitudinal direction of the passage such that plasma ions and electrons are directed by the electric field toward the plate elements.

186. The apparatus of claim 184, further comprising a plasma filter separating a first portion of the process chamber from a second portion of the process chamber, wherein the plasma filter filters plasma passing from the first portion of the process chamber to a second portion of the process chamber away from the first portion of the process chamber, and wherein the plasma filter includes:

a plurality of operably connected coil elements, wherein the plurality of operably connected coil elements form a plurality of effective coils disposed within the process chamber, wherein the plurality of effective coils are adjacently spaced apart to form a coil layer separating the first portion of the process chamber from the second portion of the process chamber; and

a drive element operably coupled to the plurality of operably connected coil elements, wherein the drive element generates an effective closed loop

current at each of the plurality of effective coils so as to induce a magnetic field at each of the plurality of effective coils, and wherein magnetic fields induced at the plurality of effective coils filter the plasma to allow plasma to flow to the second portion of the process chamber.

5

187. A method for filtering and neutralizing plasma particles within a process chamber, the method comprising the steps of:

(a) generating a plasma within a first portion of the process chamber; and

10

(b) operably coupling a plurality of coil elements within the process chamber to form a plurality of effective coils that are adjacently spaced apart to form a coil layer; and

15

(c) generating an effective closed loop current in each of the plurality of coil elements so as to induce a magnetic field at each of the plurality of effective coils to thereby filter plasma passing from the first portion of the process chamber to a second portion of the process chamber away from the first portion of the process chamber; and

20

(d) selectively biasing a plasma neutralizing grid with respect to the plurality of effective coils to cause plasma electrons and plasma ions to obtain a substantially identical velocity so that at least a portion of the plasma electrons and plasma ions recombine to form neutralized particles.

25

188. The method of claim 187, wherein step (c) includes connecting the plurality of coil elements so as to allow the plasma to induce a current in the plurality of effective coils.

189. The method of claim 187, wherein step (c) includes coupling a drive element to the plurality of coil elements so as to generate an effective closed loop current at each of the plurality of effective coils.

5 190. The method of claim 187, further comprising the step of:

(e) accelerating plasma particles from the first portion of the process chamber to the second portion of the process chamber using a plasma accelerator/decelerator grid disposed substantially parallel to and adjacent the coil layer, wherein the plasma accelerator/decelerator grid is biased with respect to the plasma filter.

10

191. The method of claim 187, wherein step (b) includes orienting the operably connected coil elements such that at least one effective coil has an axis that substantially aligns with an axis of an adjacent effective coil.

15

192. The method of claim 187, wherein step (b) includes orienting the operably connected coil elements such that at least one effective coil has an axis that substantially misaligns with an axis of an adjacent effective coil.

20

193. The method of claim 187, wherein the surface treating plasma is used in an etching process to etch a surface material selected from the group consisting of silicon, polysilicon, silicon dioxides, metals, silicides, silicon nitrides, dielectrics, polymers, and alloys.

25

194. The method of claim 187, wherein the surface treating plasma is used in a deposition process wherein a material is deposited on a surface of the substrate, the material selected from the group consisting of silicon, polysilicon, silicon dioxides, metals, silicides, silicon nitrides, dielectrics, polymers, and alloys.

30

195. The method of claim 187, wherein the surface treating plasma is used in an ashing process to ash and surface clean a surface material selected from the group consisting of photoresists, polymers, and residues.

5 196. A method for filtering and neutralizing a plasma within a process chamber, the method comprising the steps of:

(a) generating a plasma within a first portion of the process chamber; and

10 (b) operably coupling a plurality of plate elements disposed within the process chamber, wherein the plurality of plate elements are spaced apart adjacently in two dimensions to form a plurality of passages, and wherein the plurality of passages form a filtering region; and

15 (c) generating an effective closed loop current in each of the plurality of plate elements to induce a magnetic field in each of the plurality of passages, wherein a magnetic field in each passage orients substantially parallel to a longitudinal direction of the passage such that positive ions and electrons of the plasma are directed by the magnetic field to filter and neutralize the  
20 plasma.

197. The method of claim 196, further comprising the step of:

25 (d) selectively biasing a plasma neutralizing grid with respect to the plurality of plate elements to cause plasma electrons and plasma ions to obtain a substantially identical velocity so that at least a portion of the plasma electrons and plasma ions recombine to form neutralized particles.

198. The method of claim 196, wherein step (c) includes connecting the plurality of plates elements so as to allow the plasma to induce a current in the plurality of effective coils.

5 199. The method of claim 196, wherein step (c) includes coupling a drive element to the plurality of plate elements so as to generate an effective closed loop current at each of the plurality of passages.

200. The method of claim 196, further comprising the step of:

10

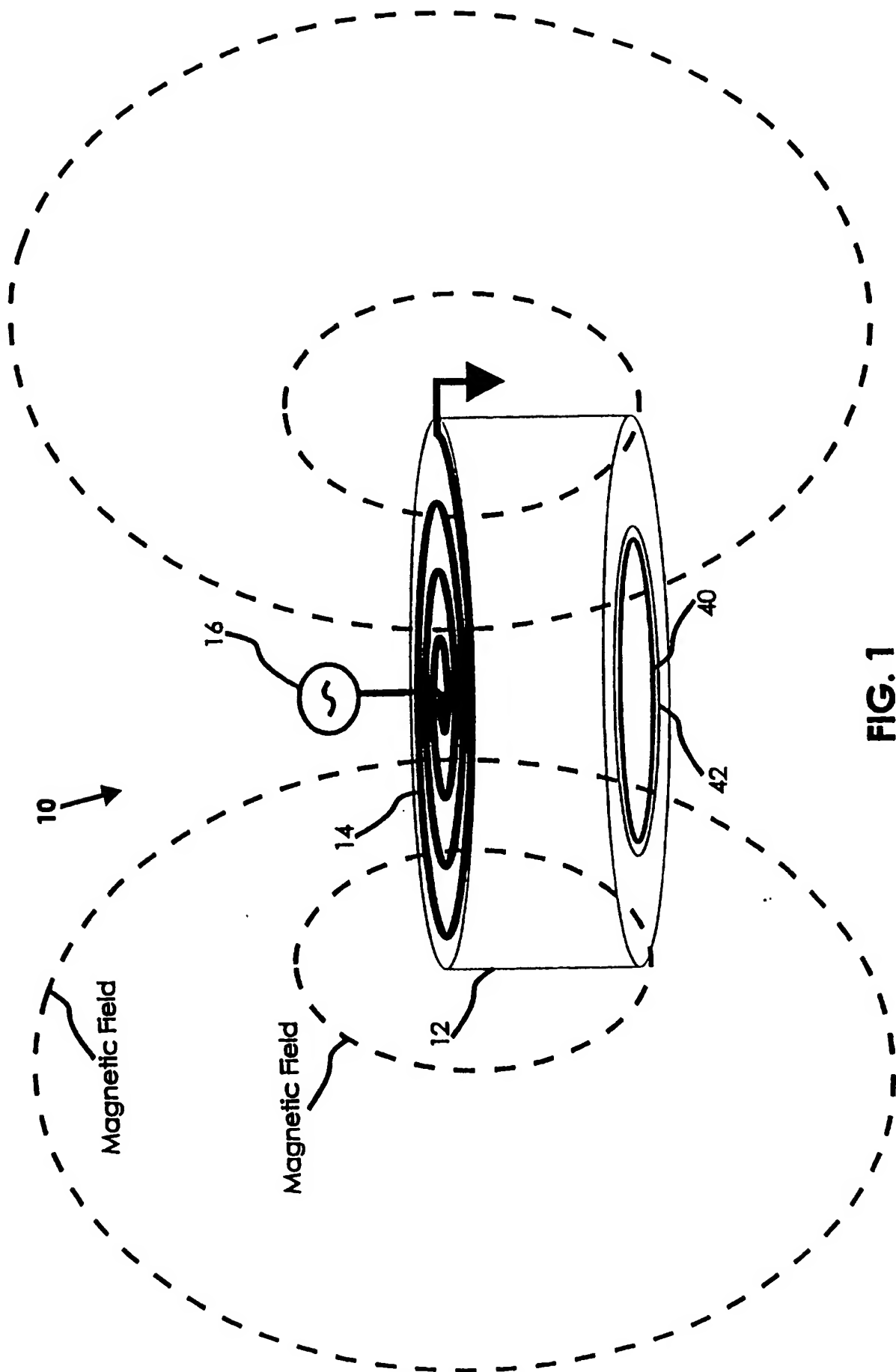
(d) accelerating plasma particles from the first portion of the process chamber to the second portion of the process chamber using a plasma accelerator/decelerator grid disposed substantially parallel to and adjacent the coil layer, wherein the plasma accelerator/decelerator grid is biased with respect to the plurality of plate elements.

15

201. The method of claim 196, further comprising the step of:

(d) biasing the plurality of plate elements to induce an electric field in each of the plurality of passages, wherein the electric field in each passage orients substantially perpendicular to the longitudinal direction of the passage such that positive ions and electrons of the plasma are directed by the electric field toward the plate elements.

20



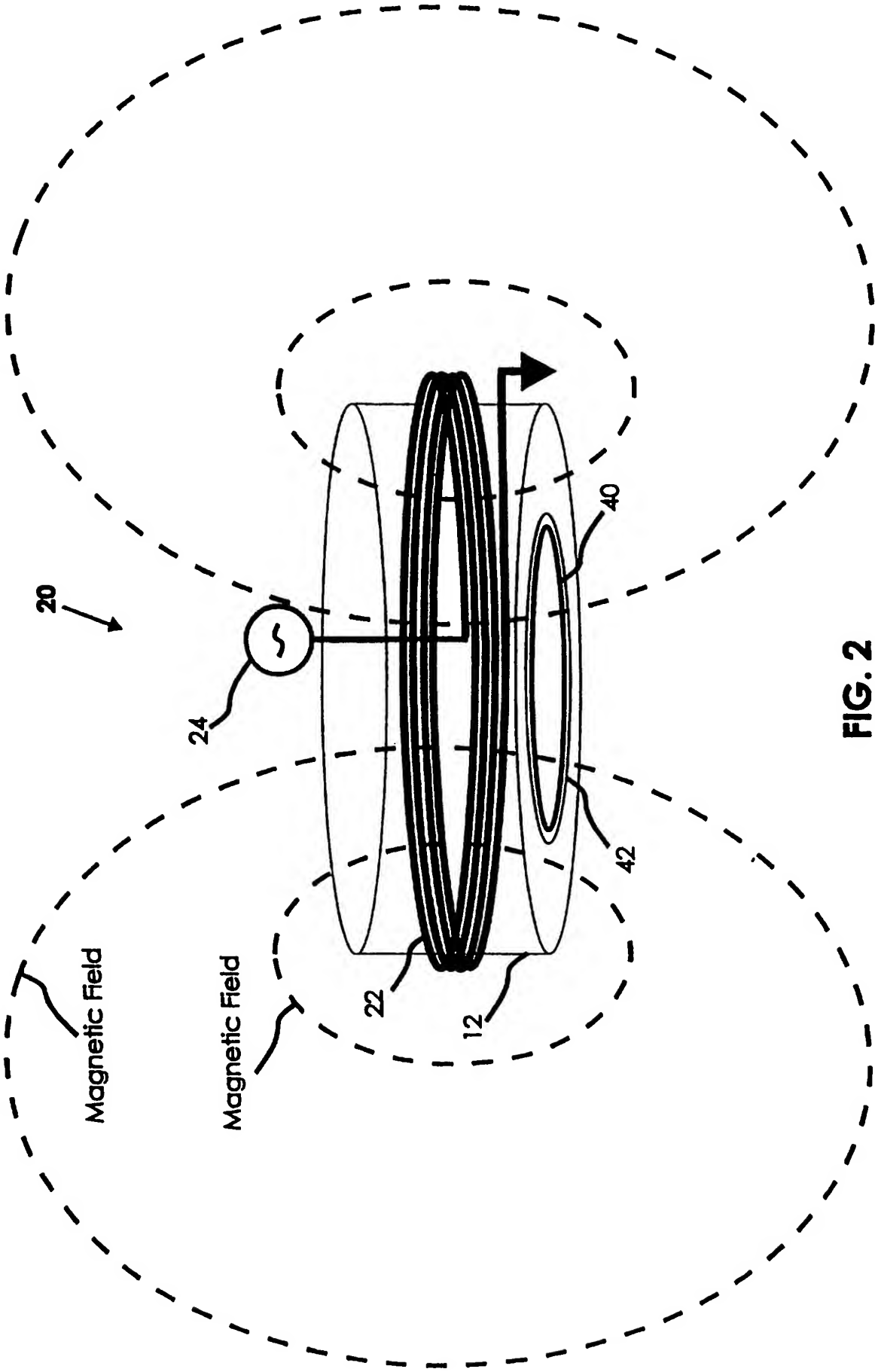


FIG. 2



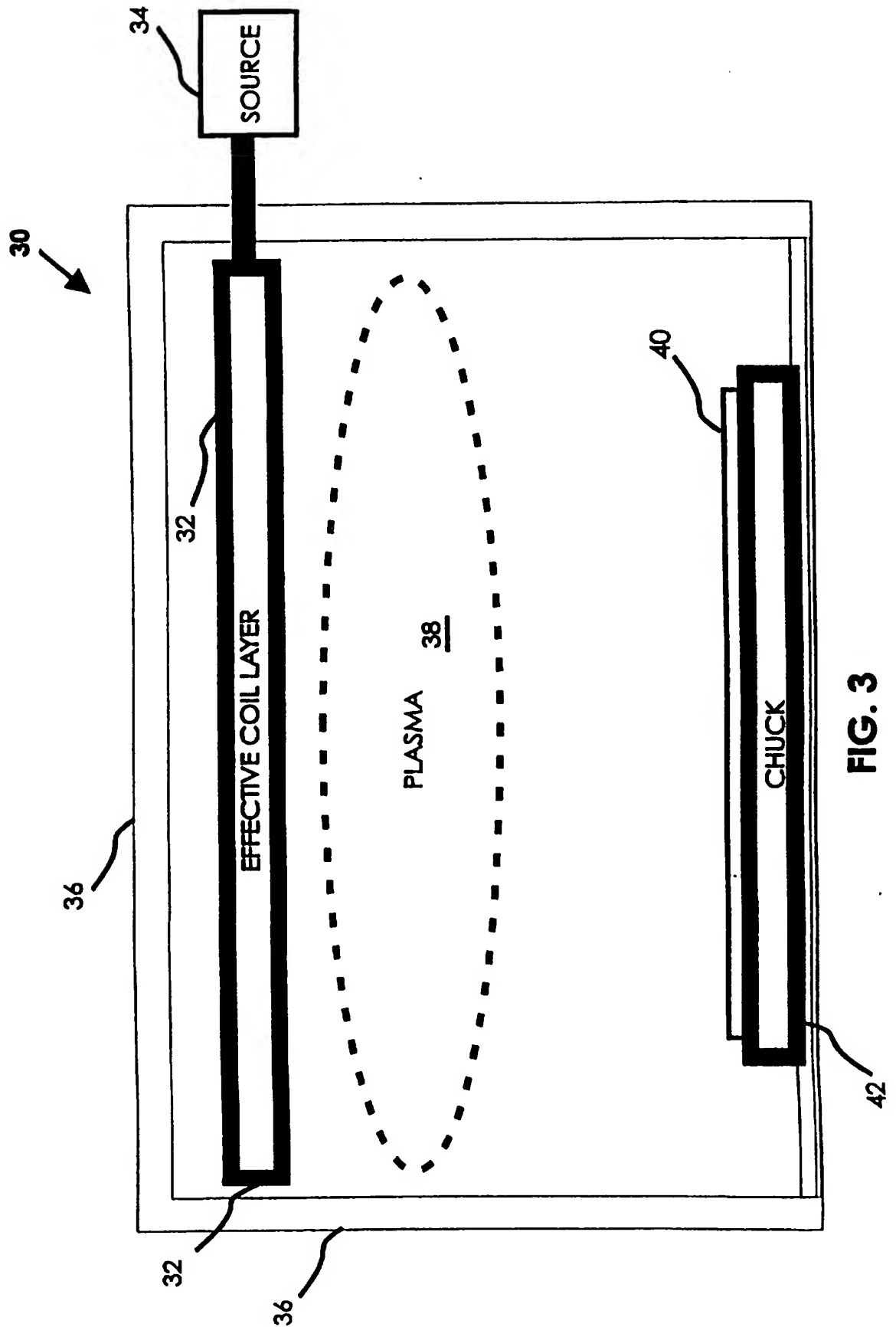


FIG. 3

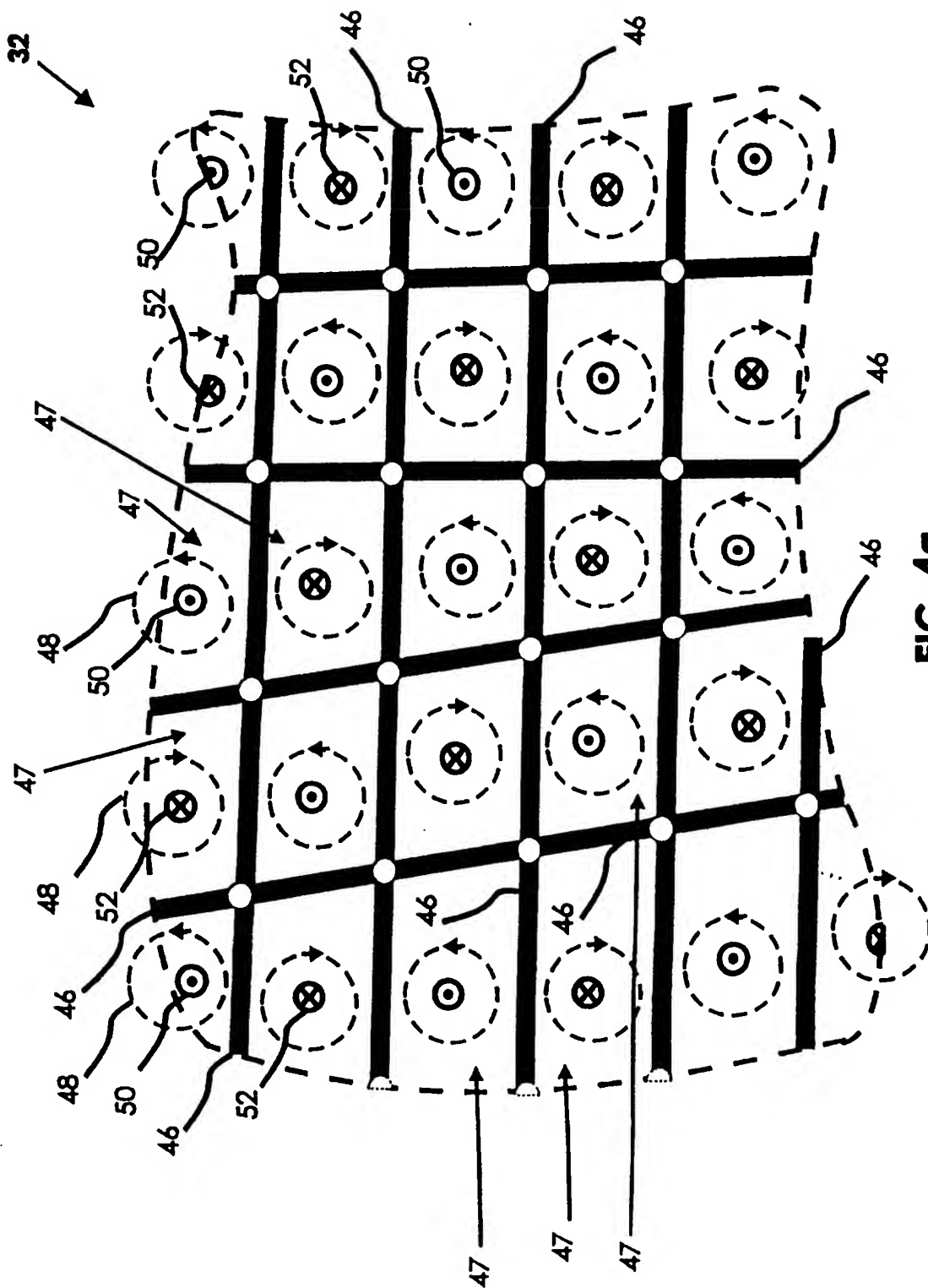


FIG. 4a

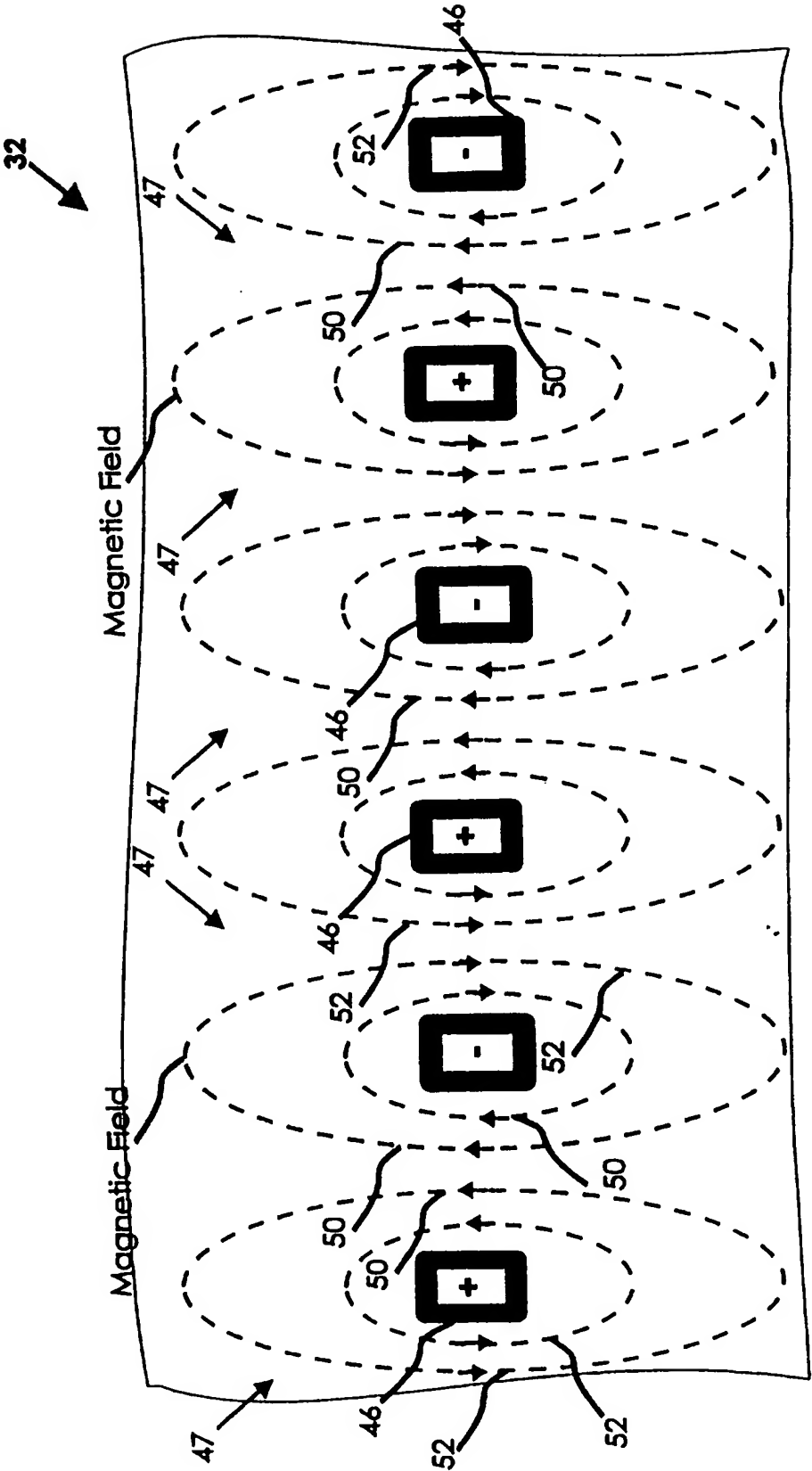


FIG. 4b

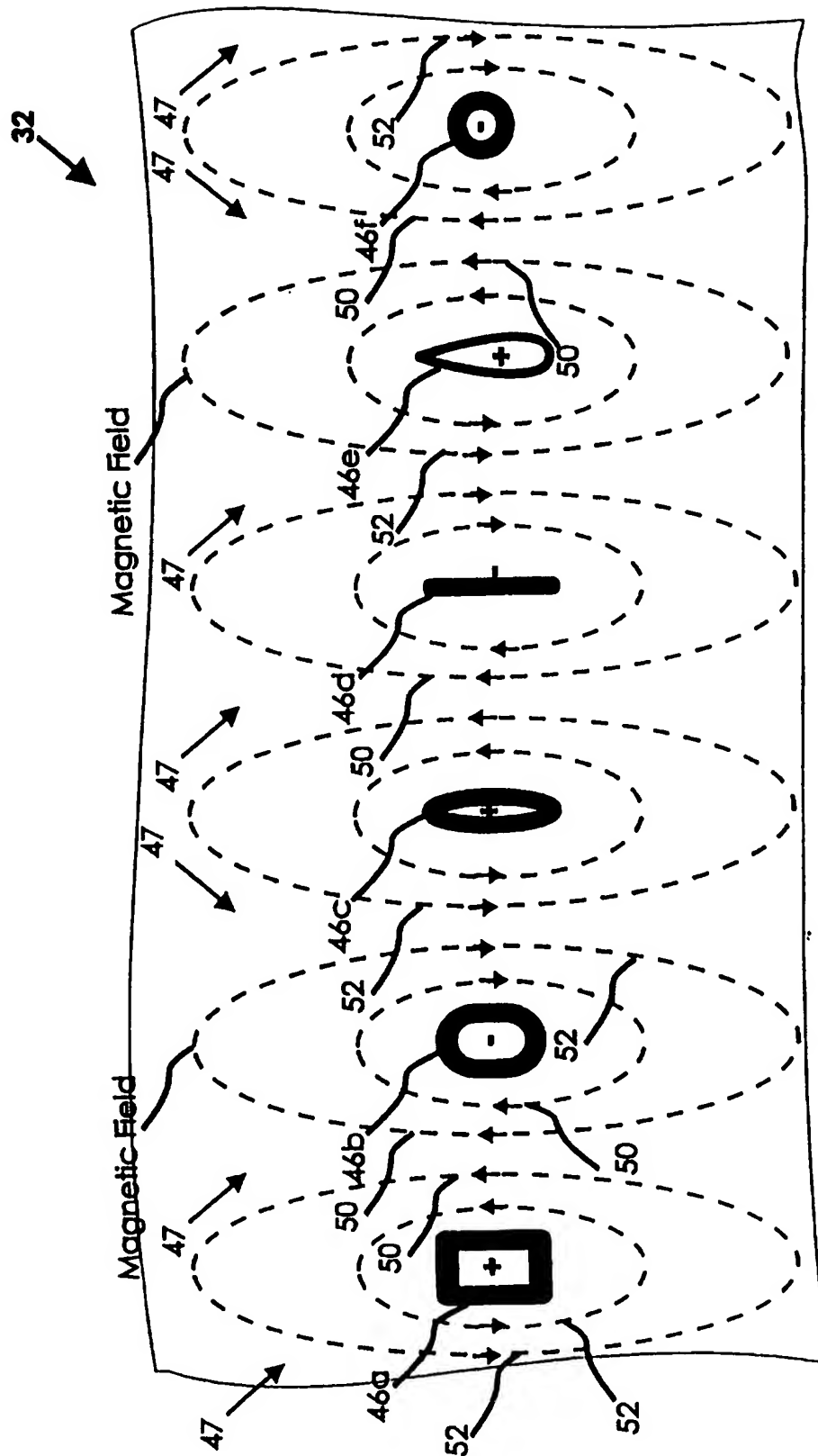


FIG. 4c

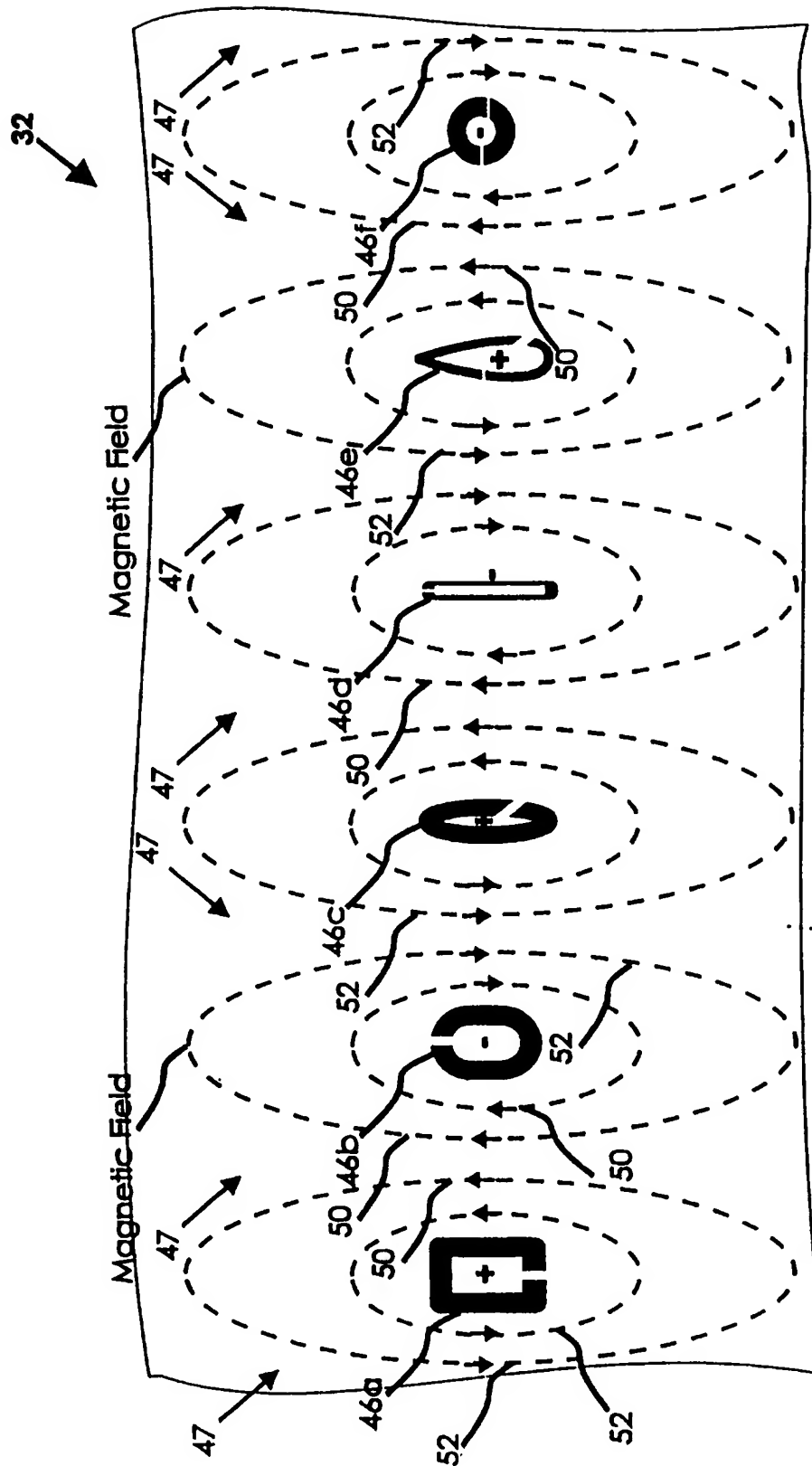


FIG. 4d

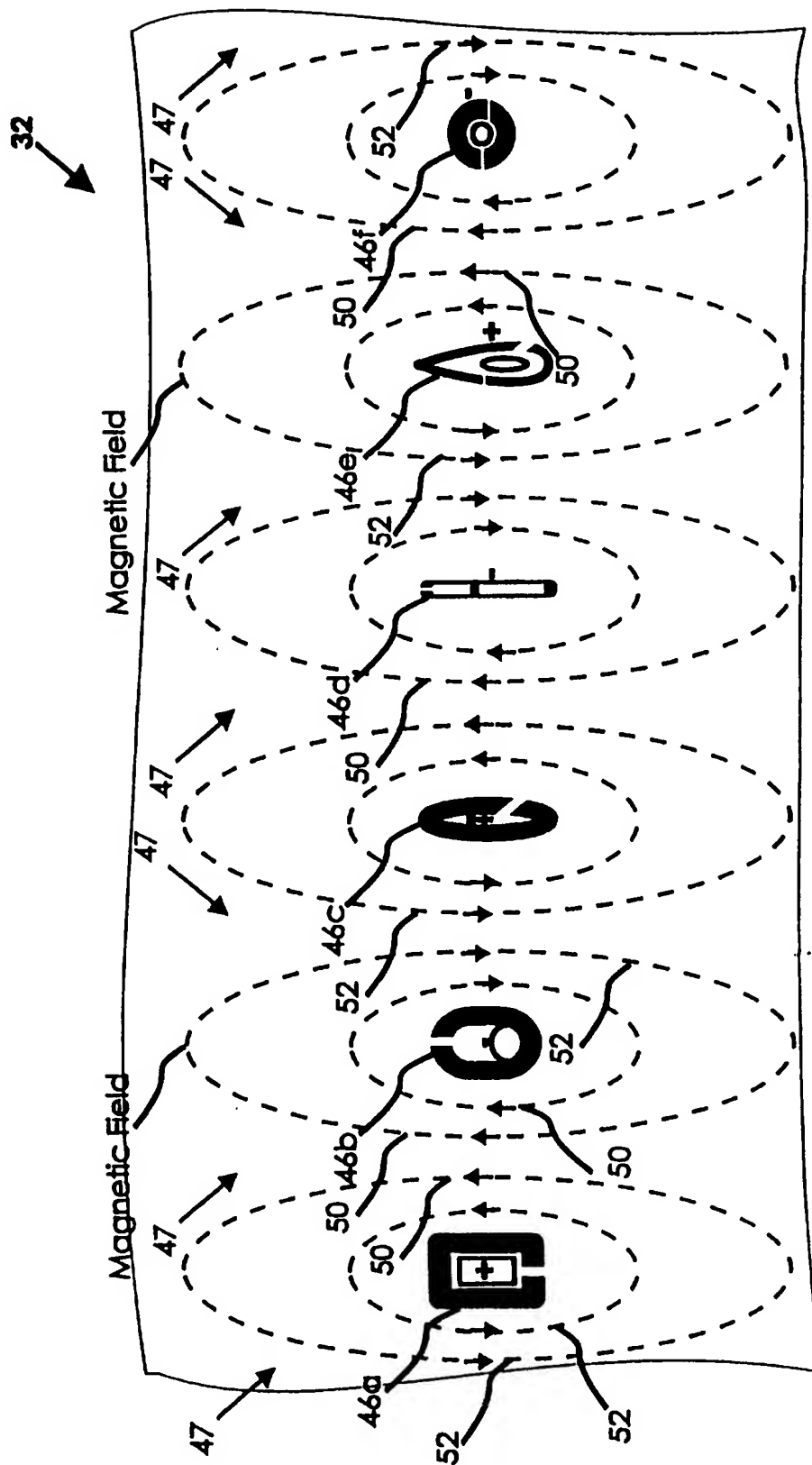


FIG. 4e

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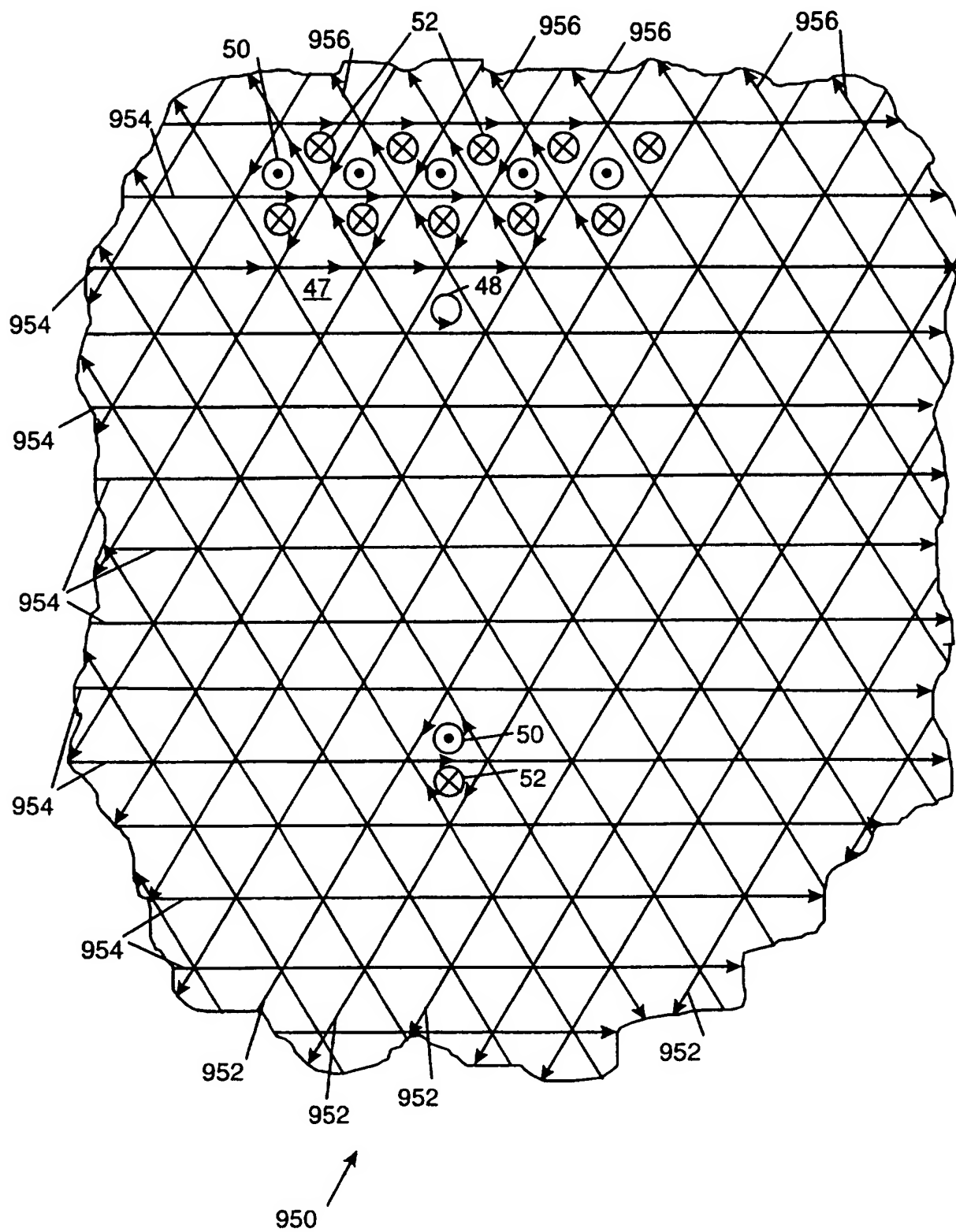


FIG. 4f

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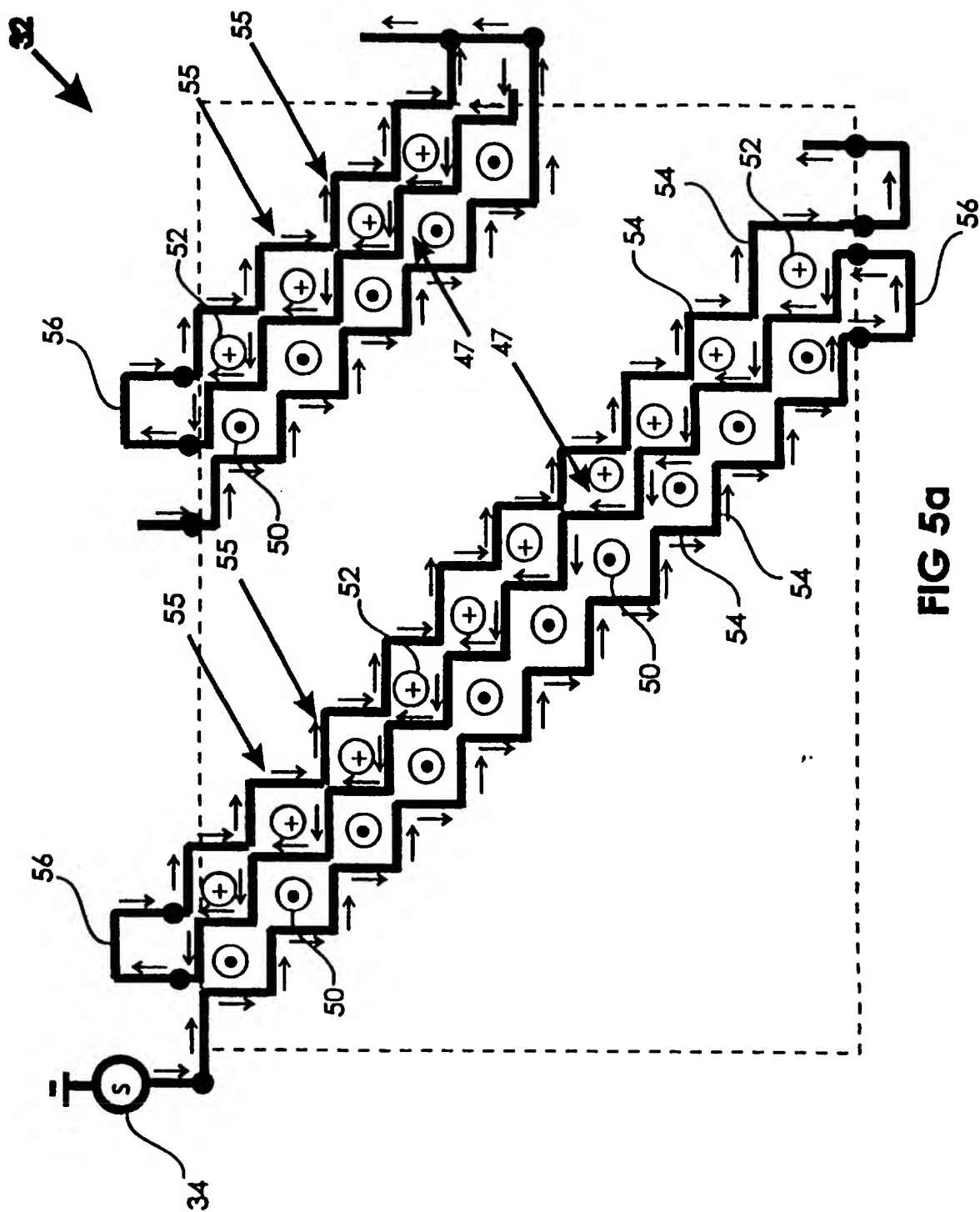


FIG 5a



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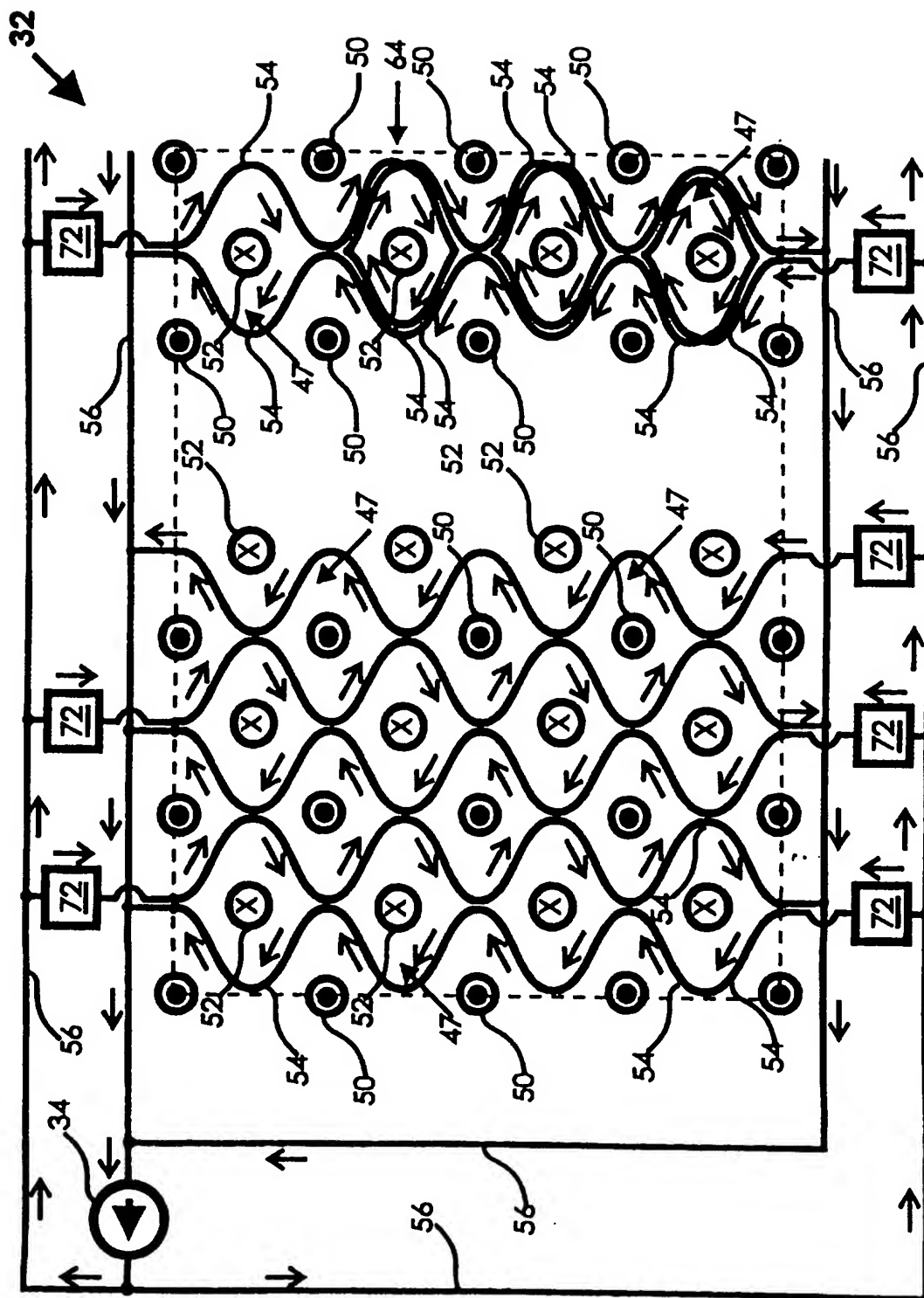


FIG 5b

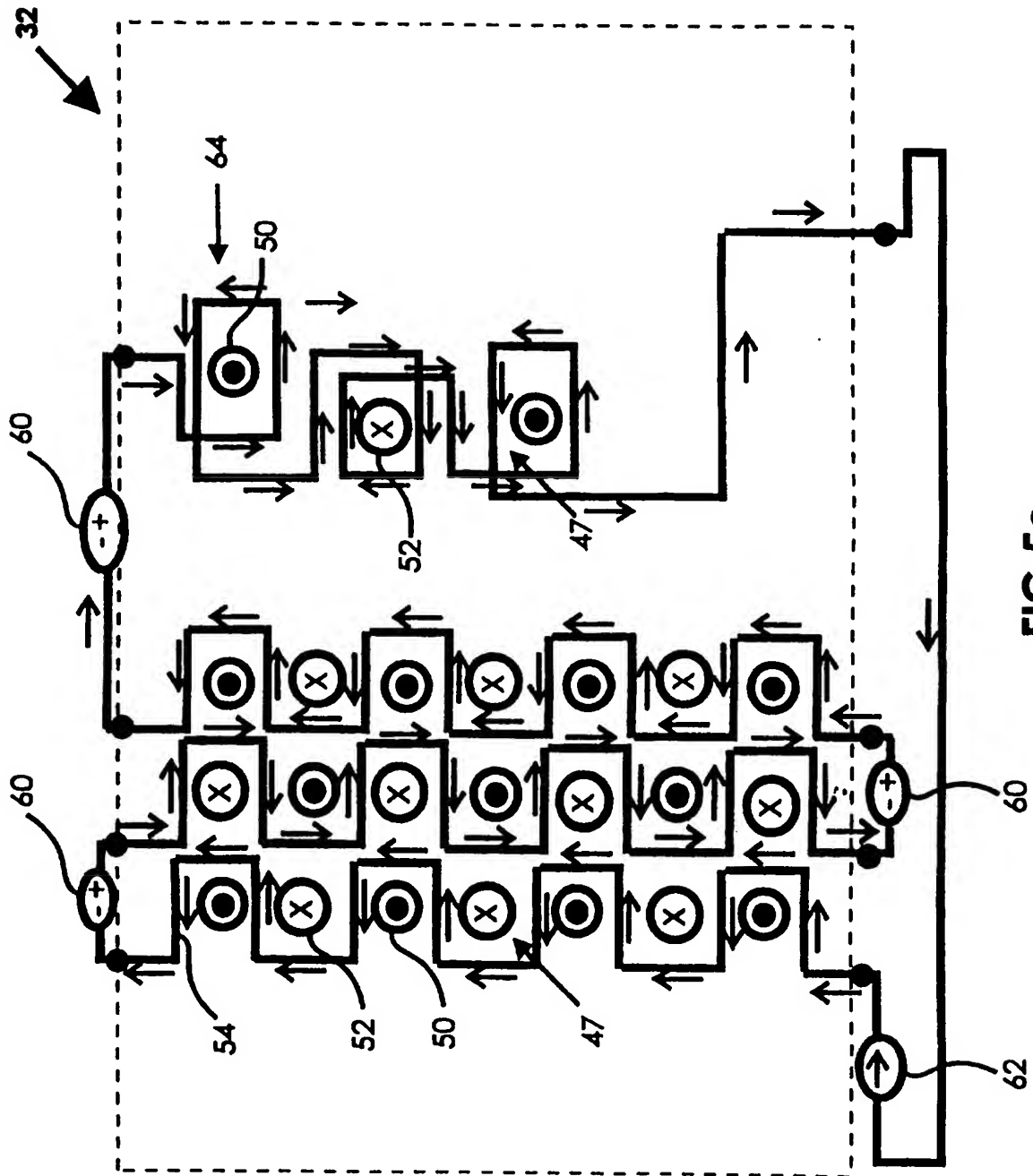


FIG 5c

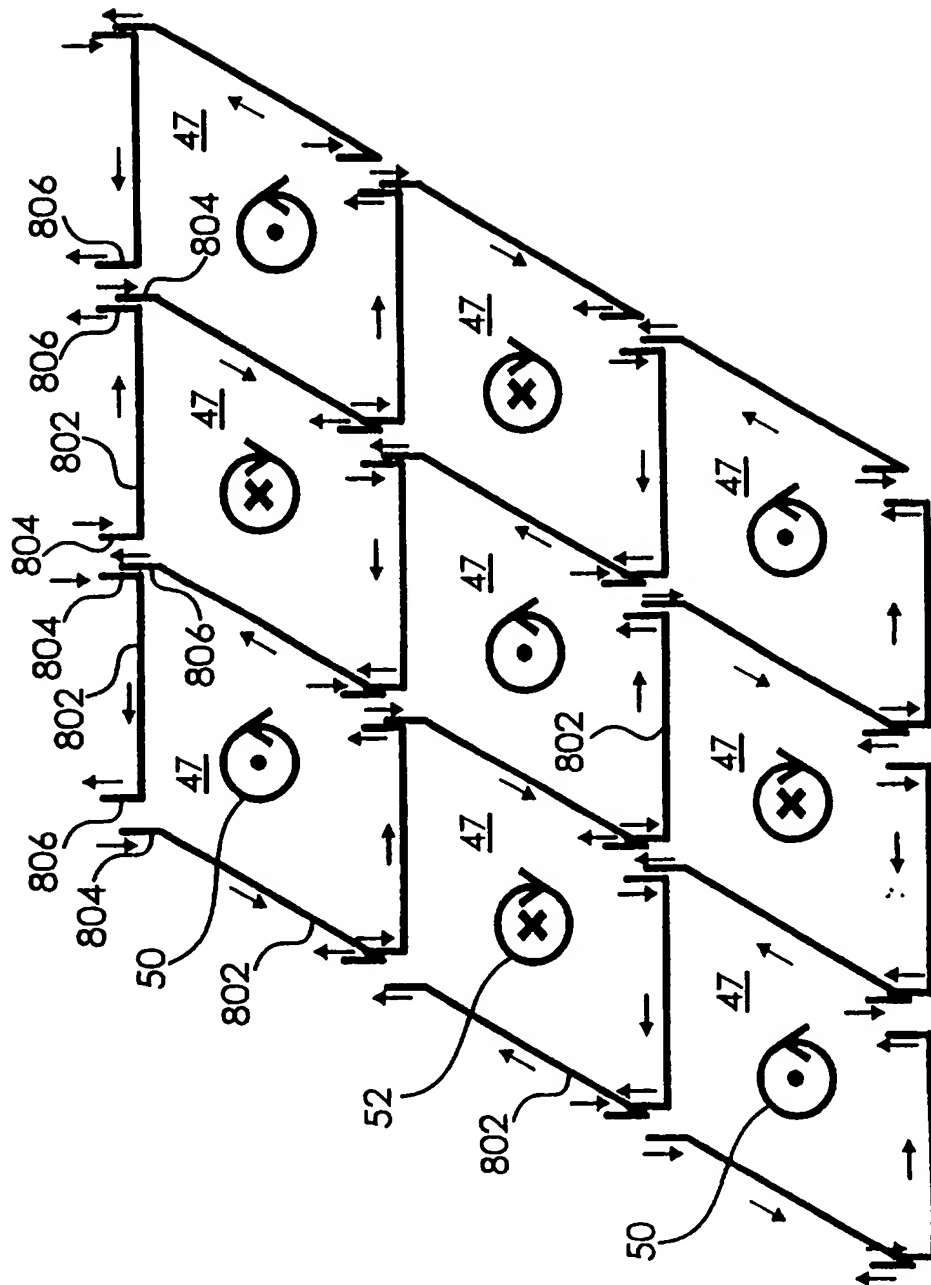


FIG 6a

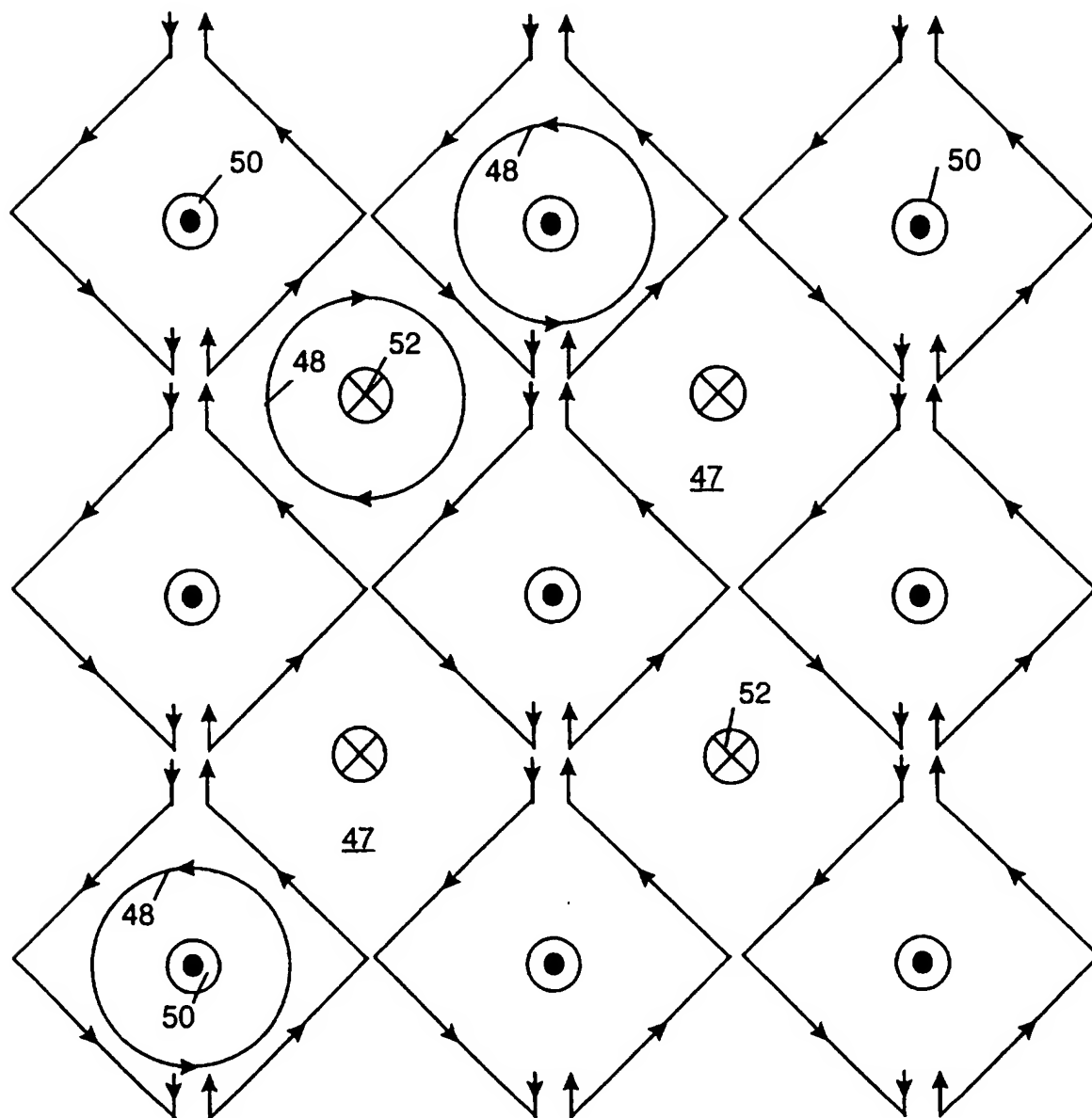


FIG. 6b

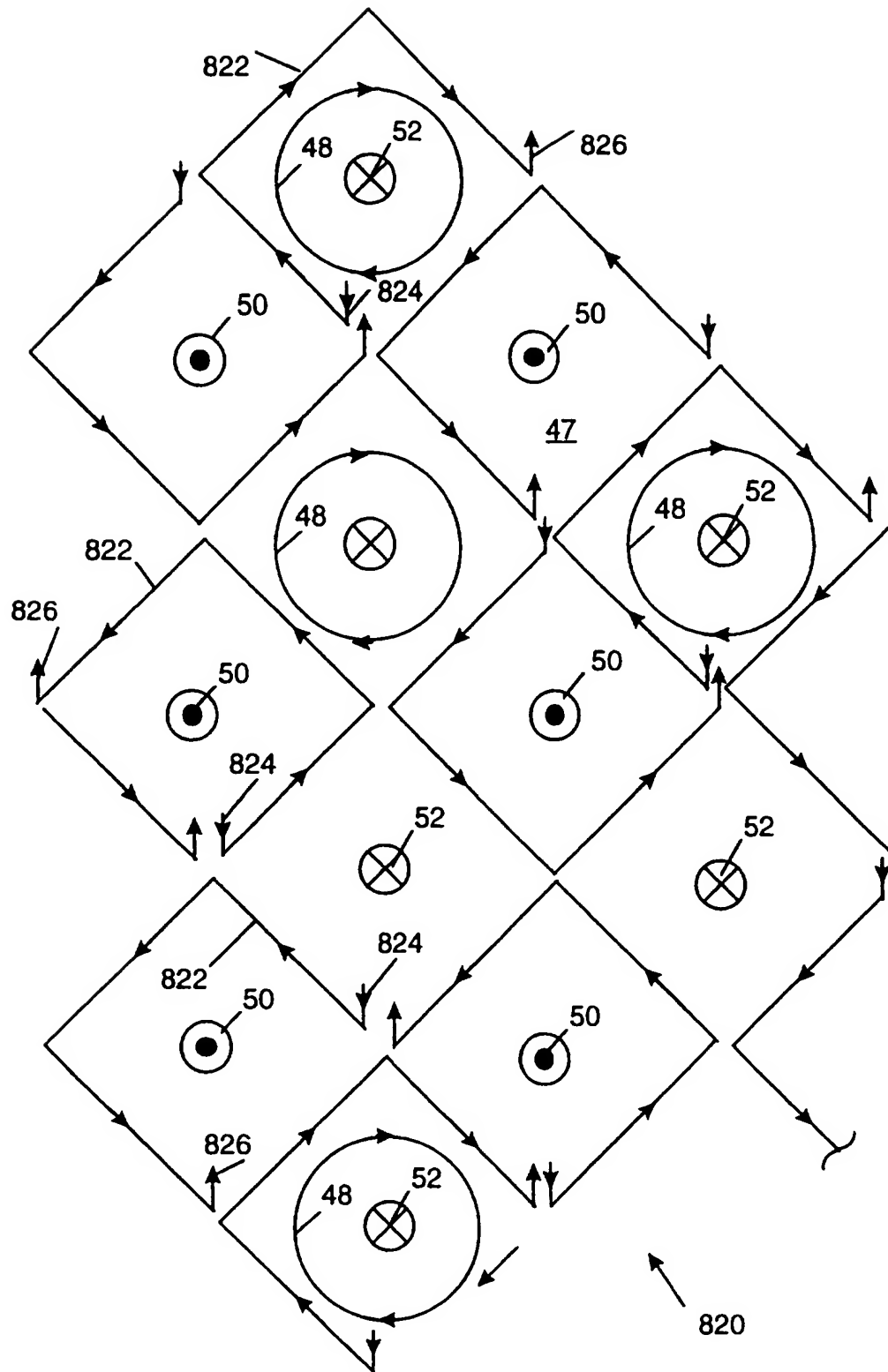


FIG. 6c

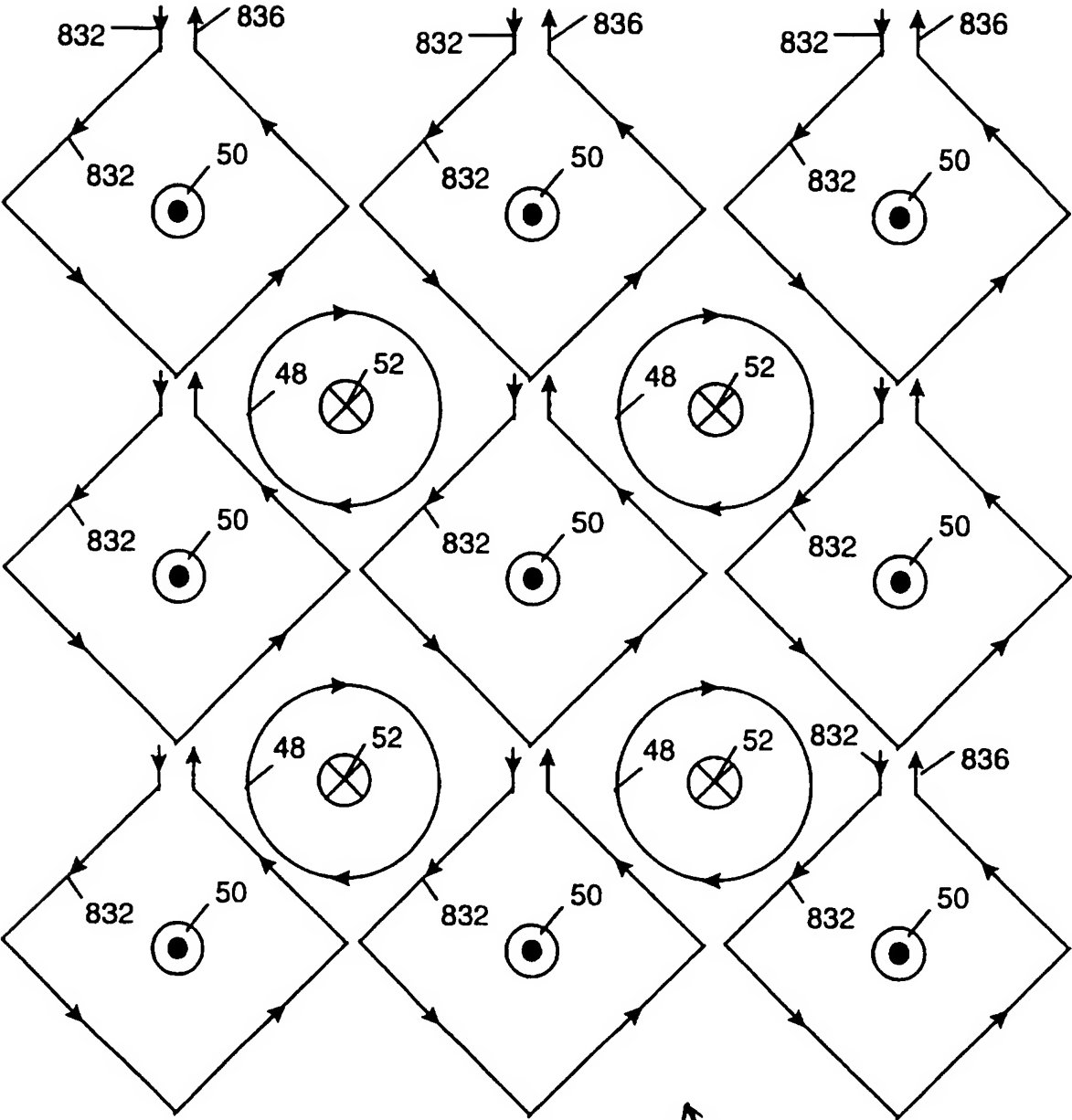


FIG. 6

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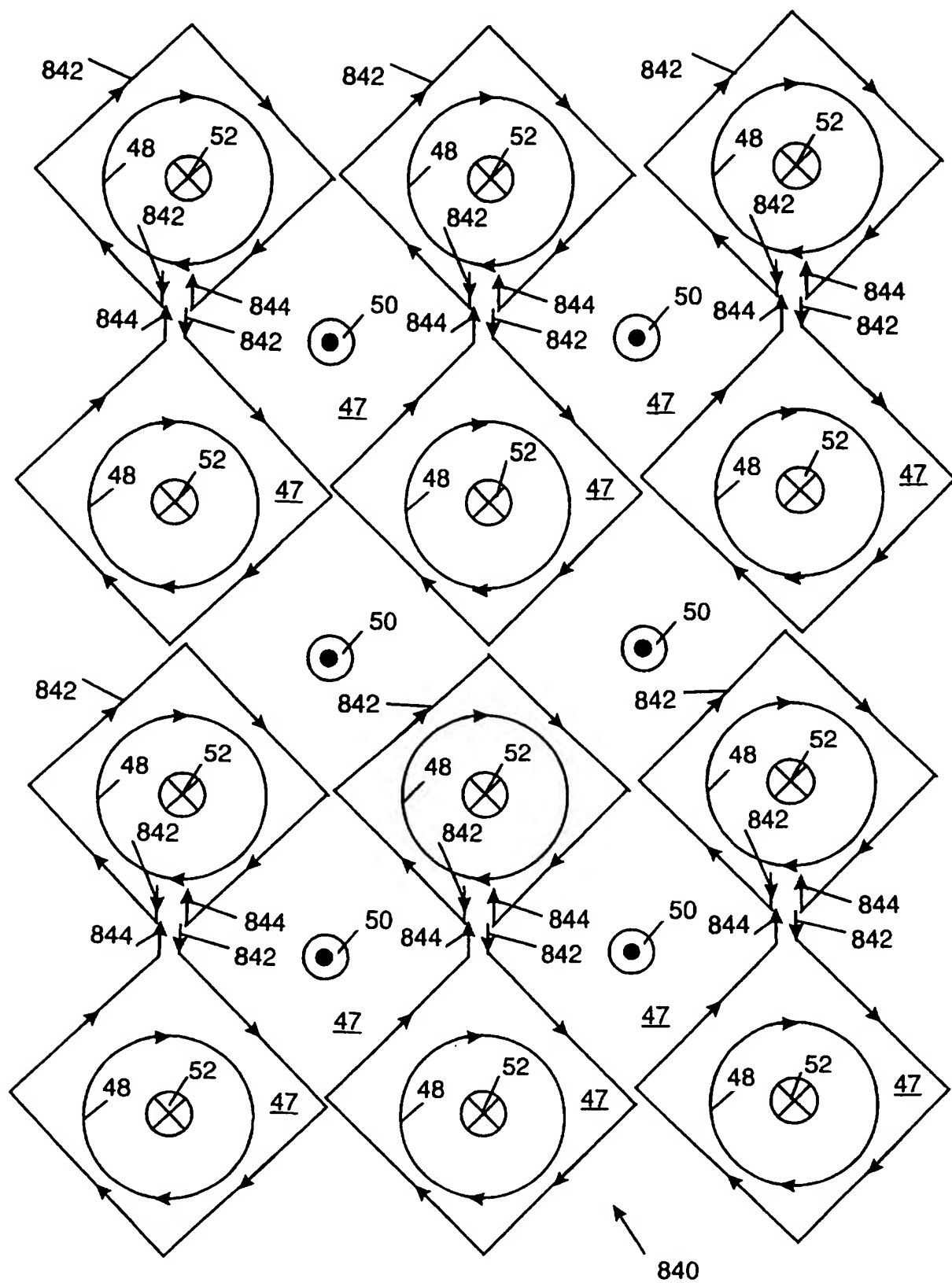
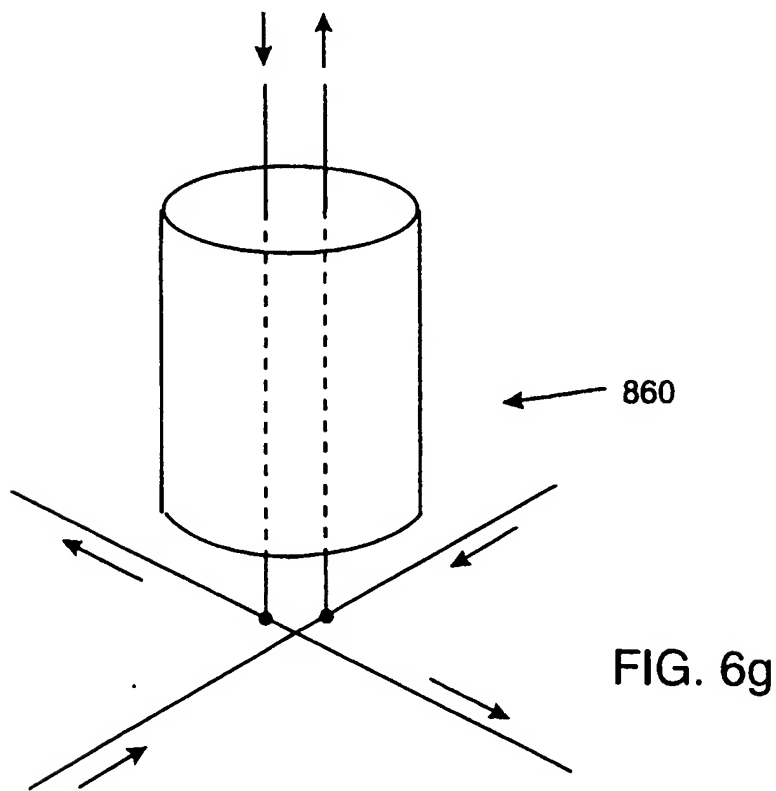
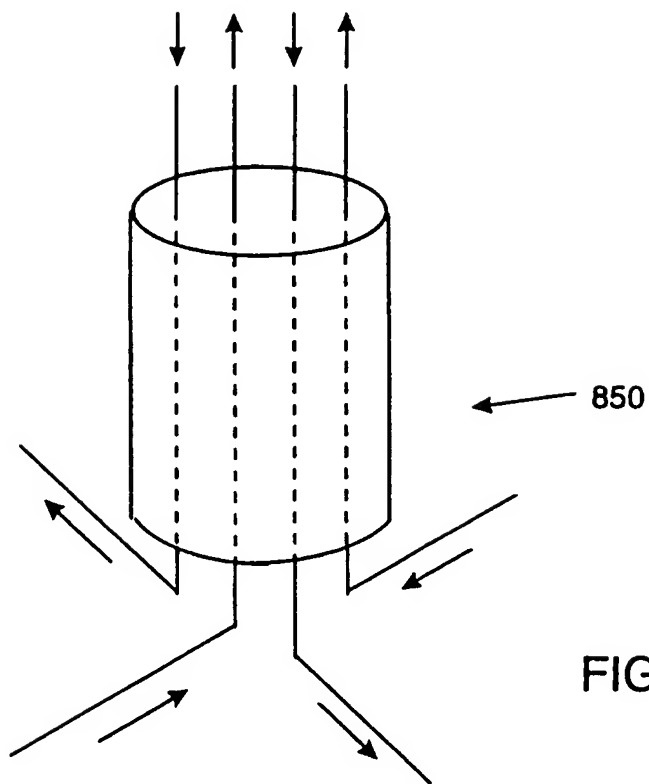


FIG. 6e





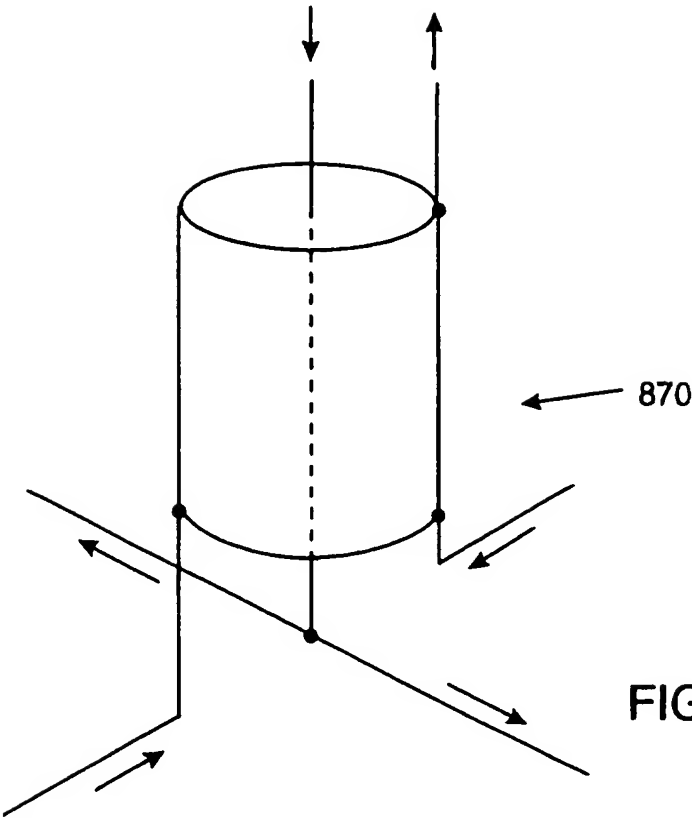


FIG. 6h

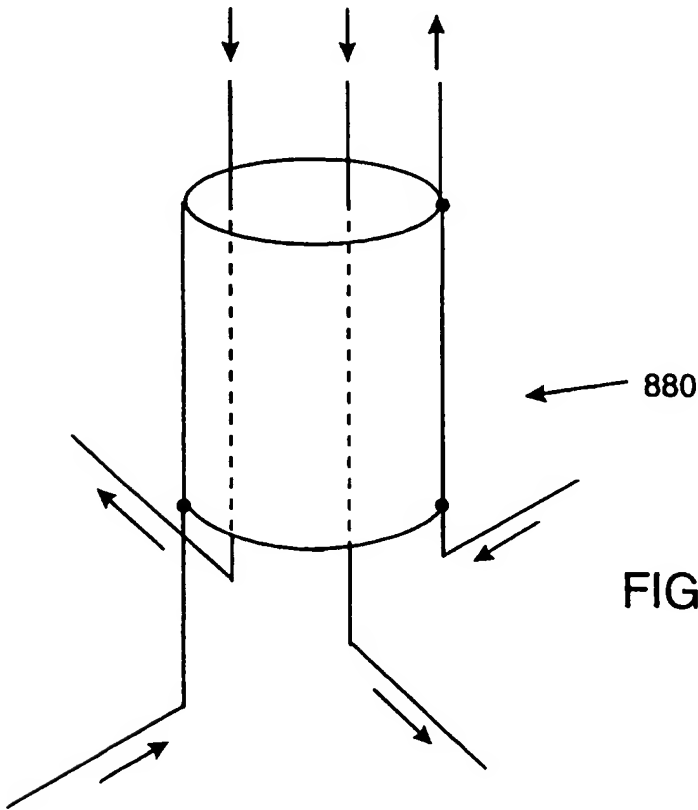
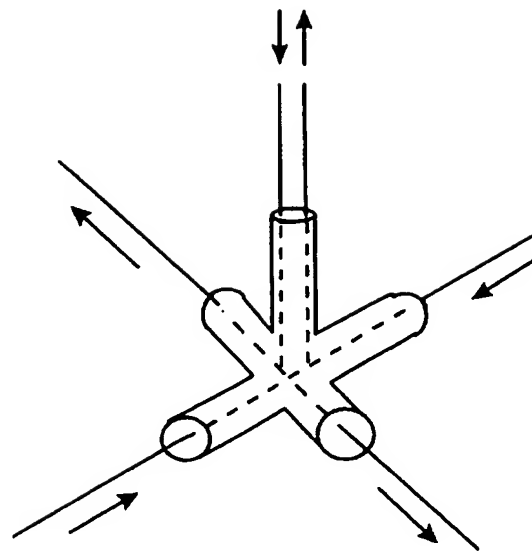


FIG. 6i



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FIG. 6j

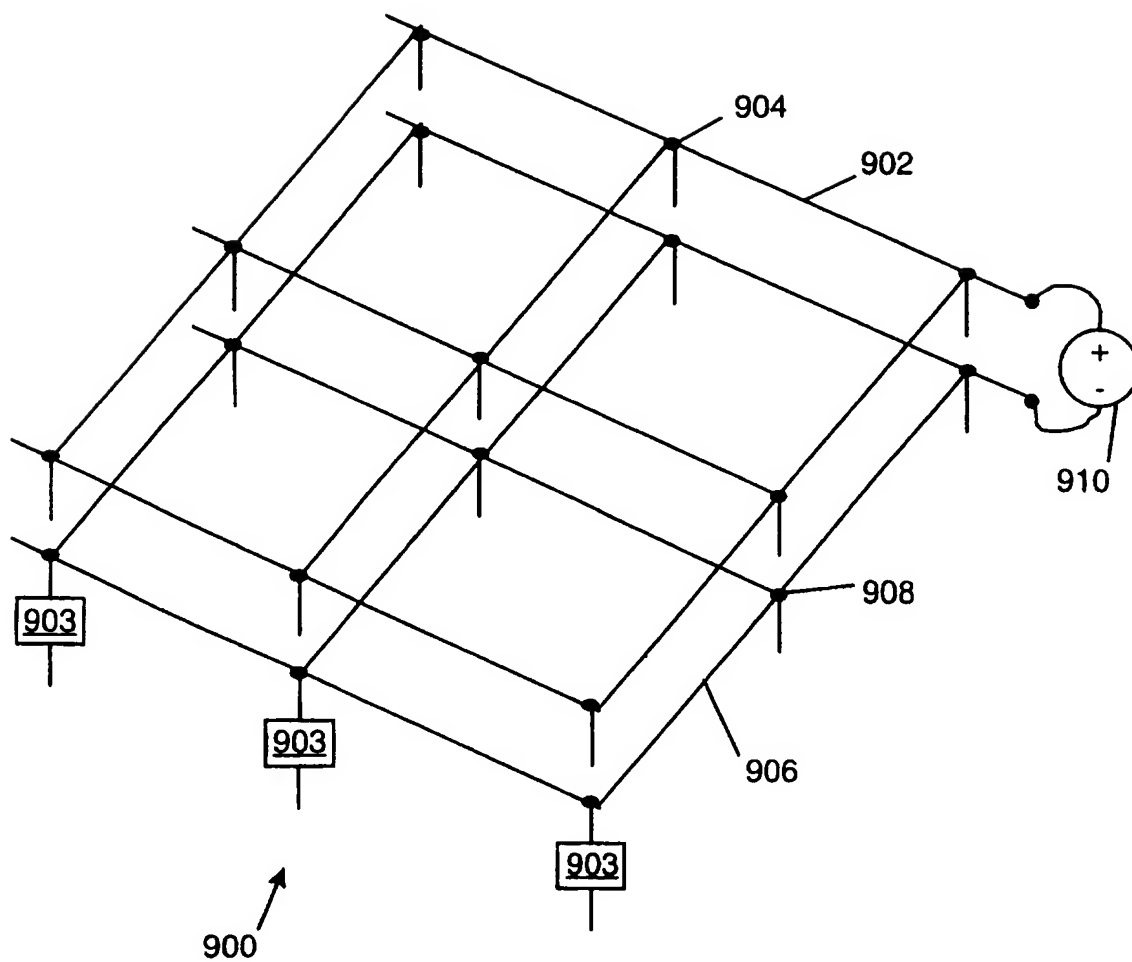


FIG. 6k

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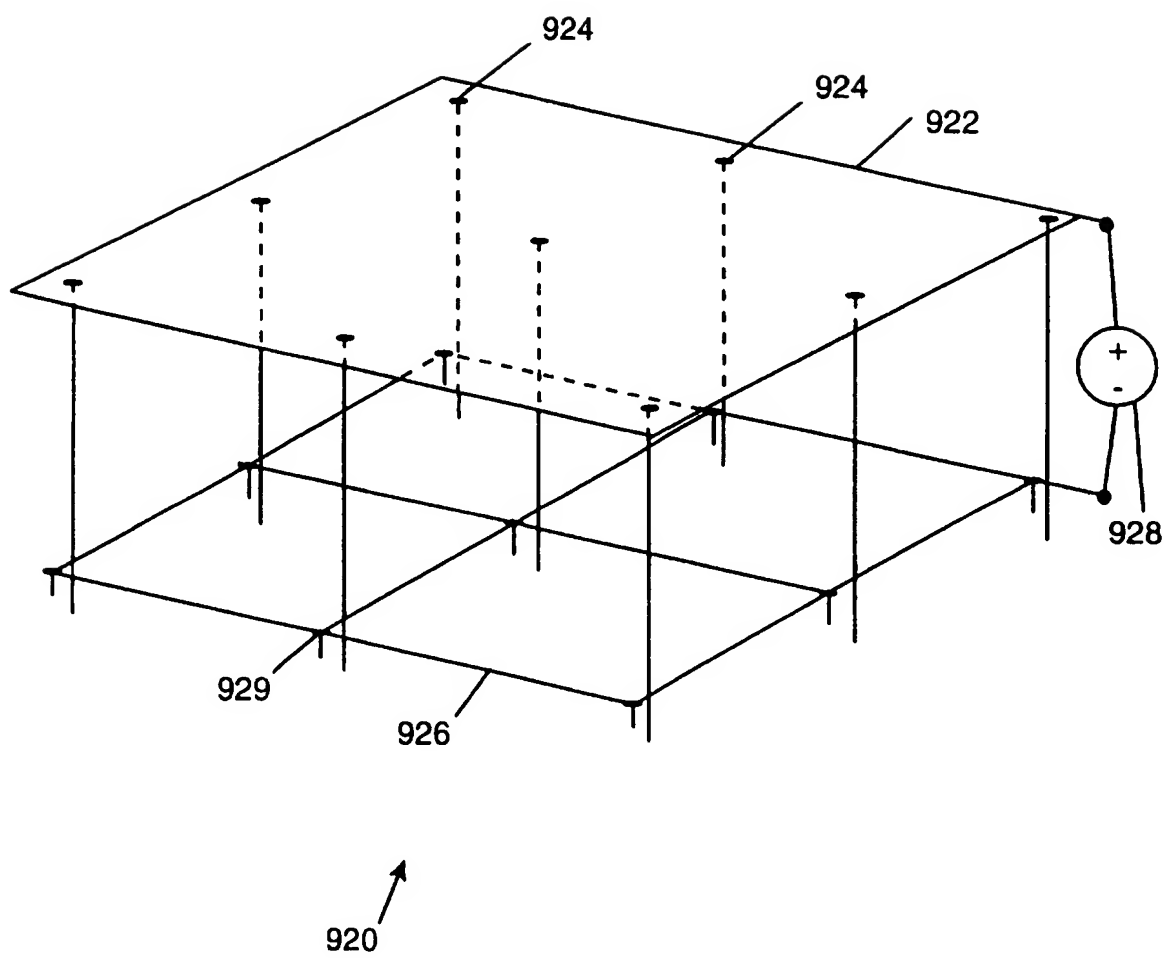


FIG. 6I



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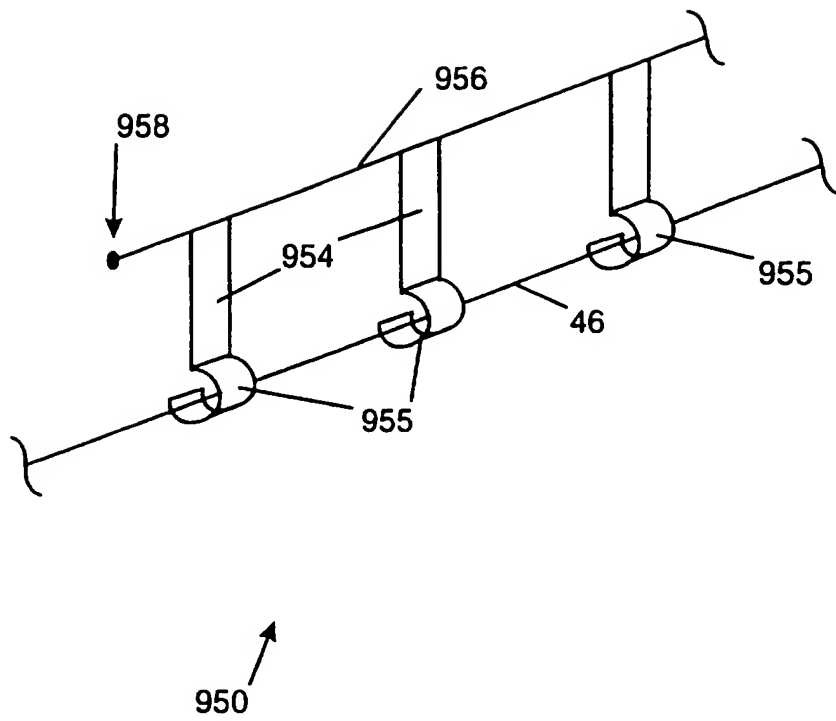


FIG. 7a

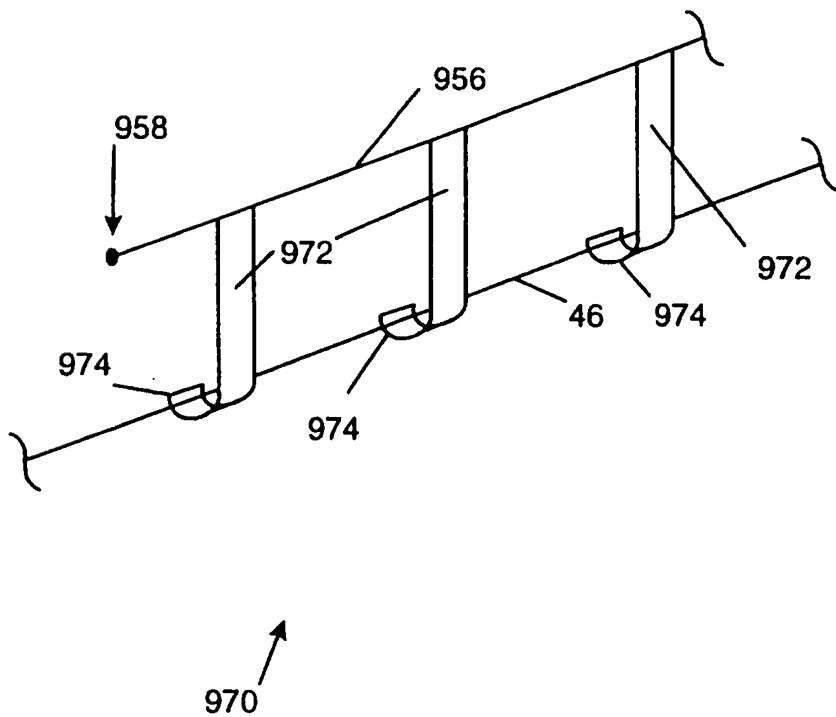


FIG. 7b

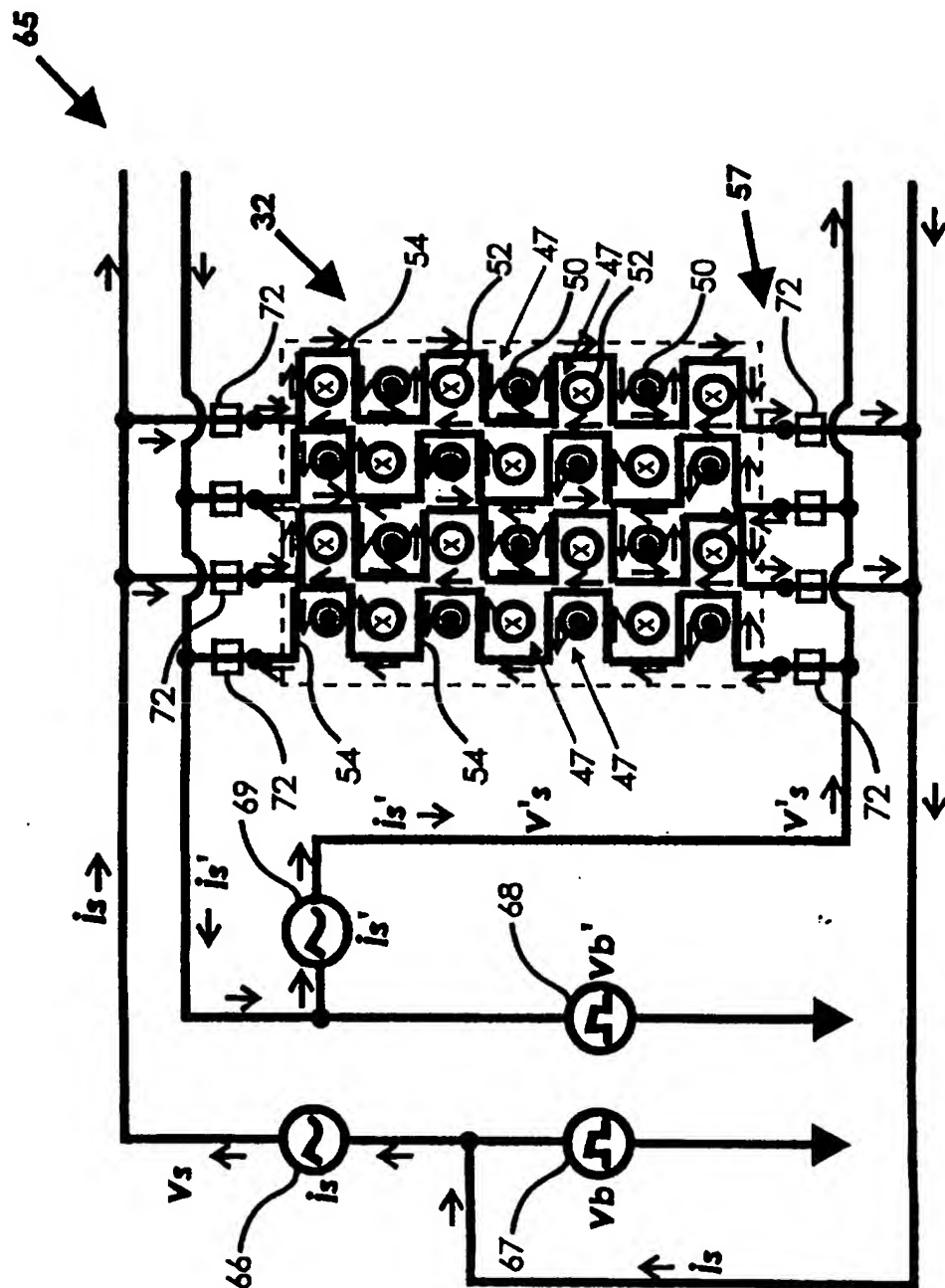
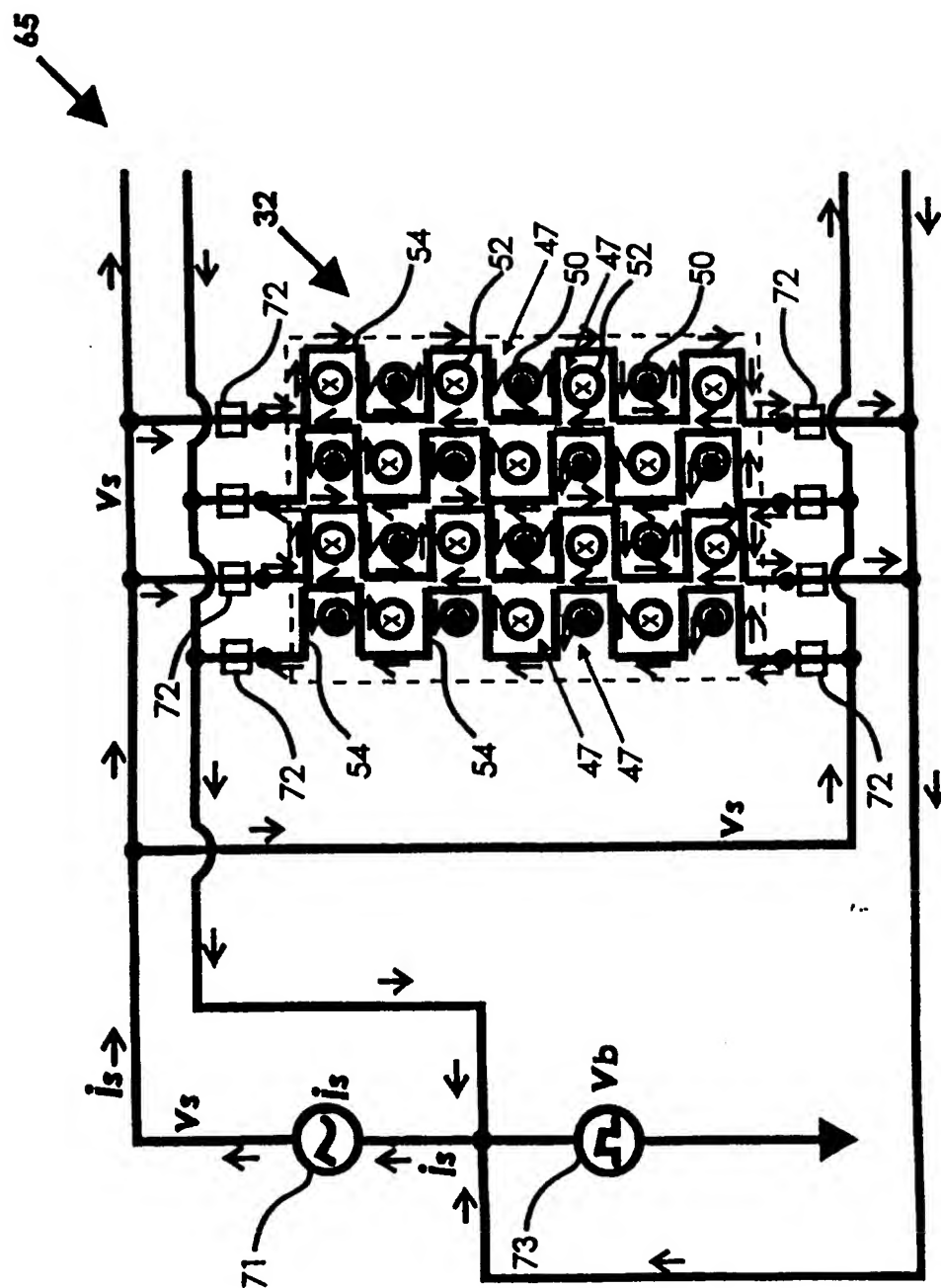


FIG 8a



**FIG 8b**



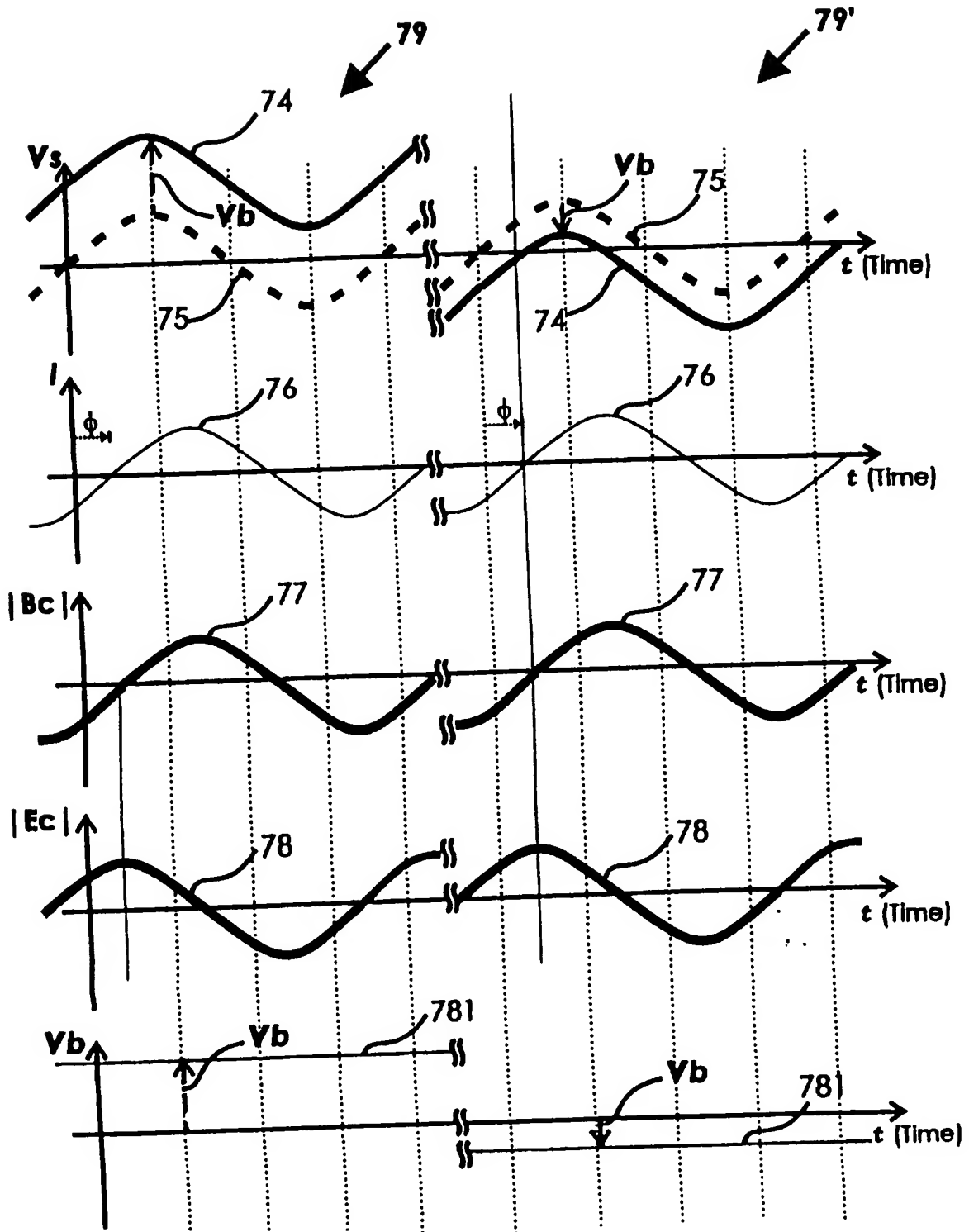


FIG 8c

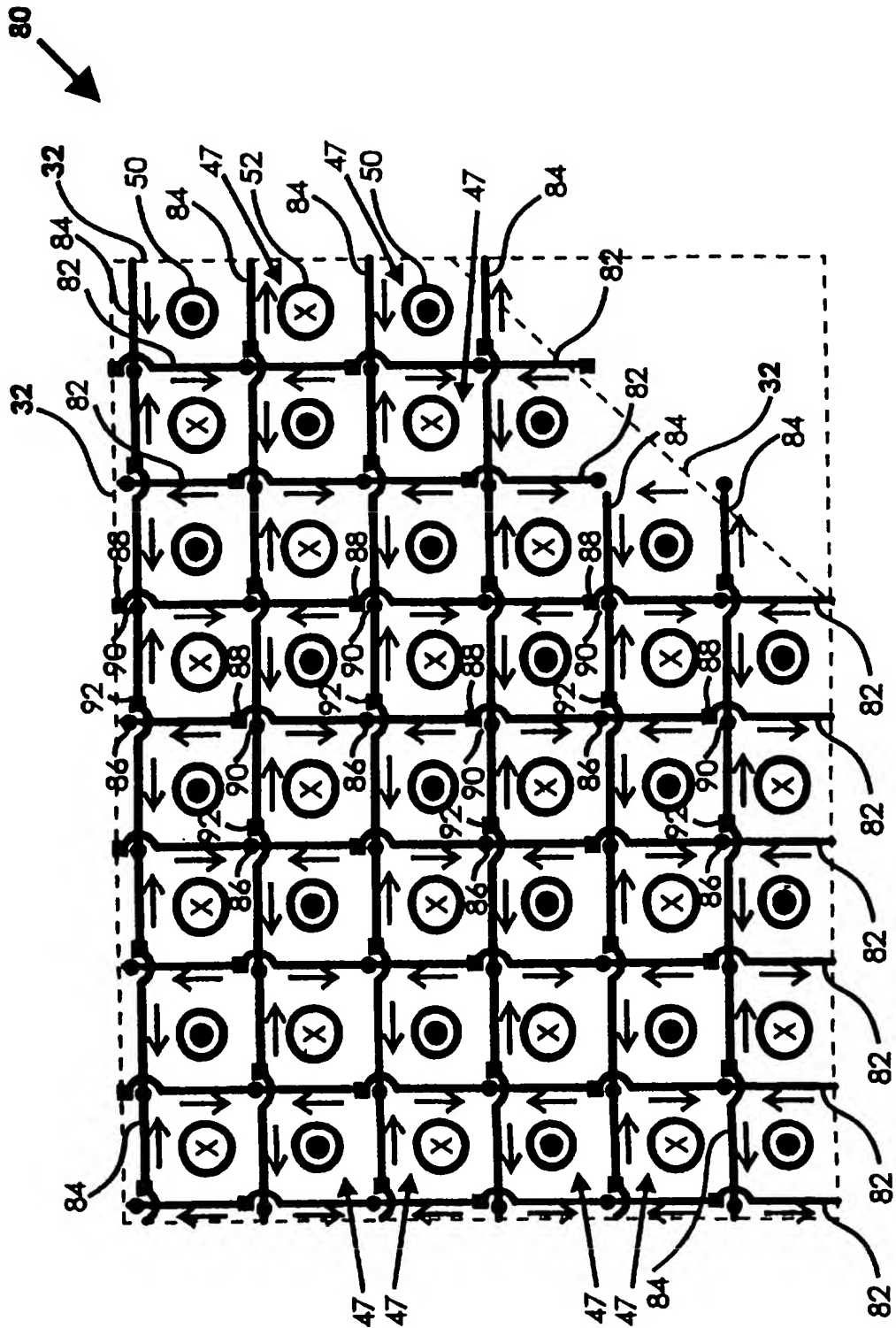


FIG 9a

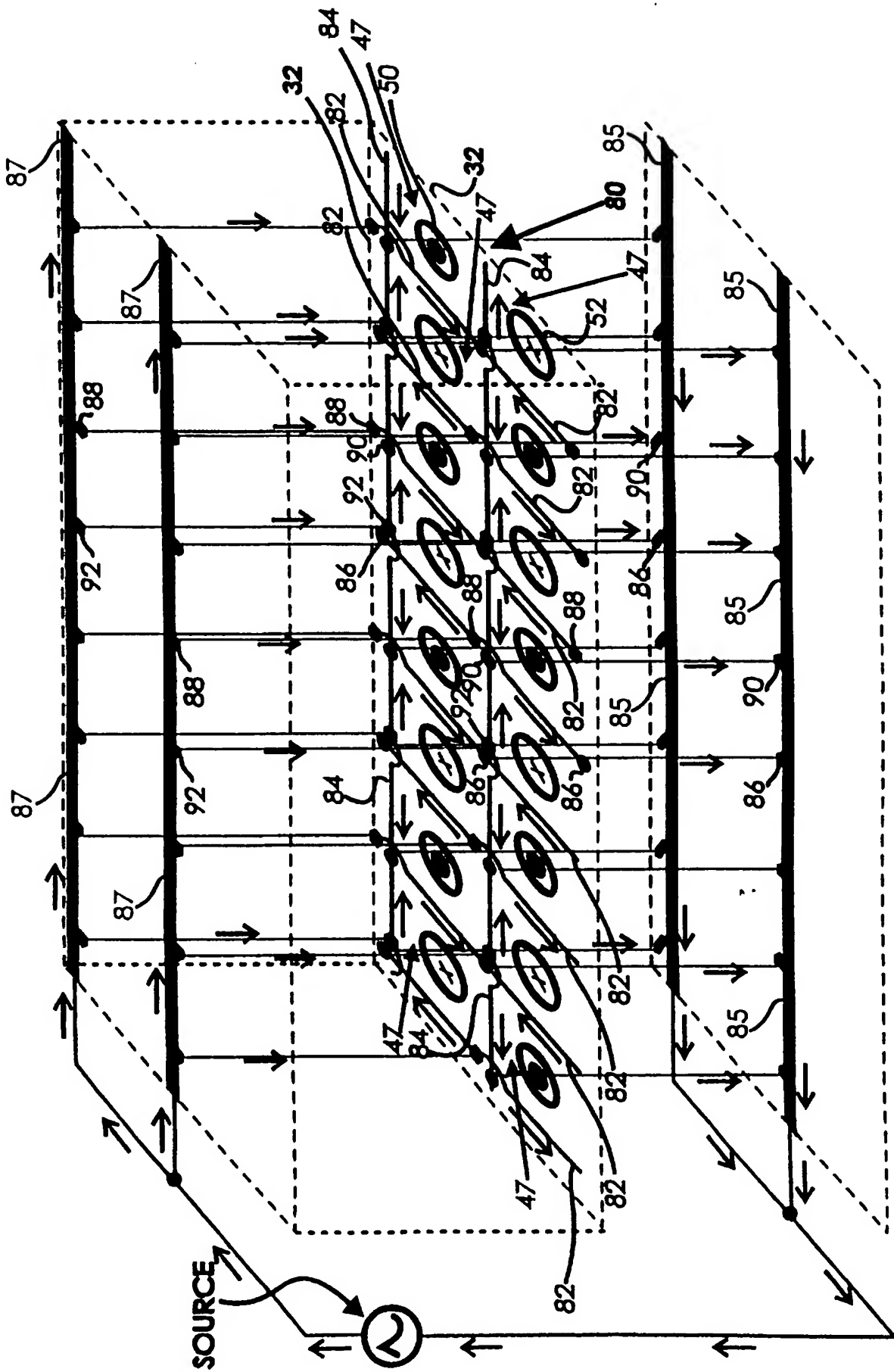


FIG 9b

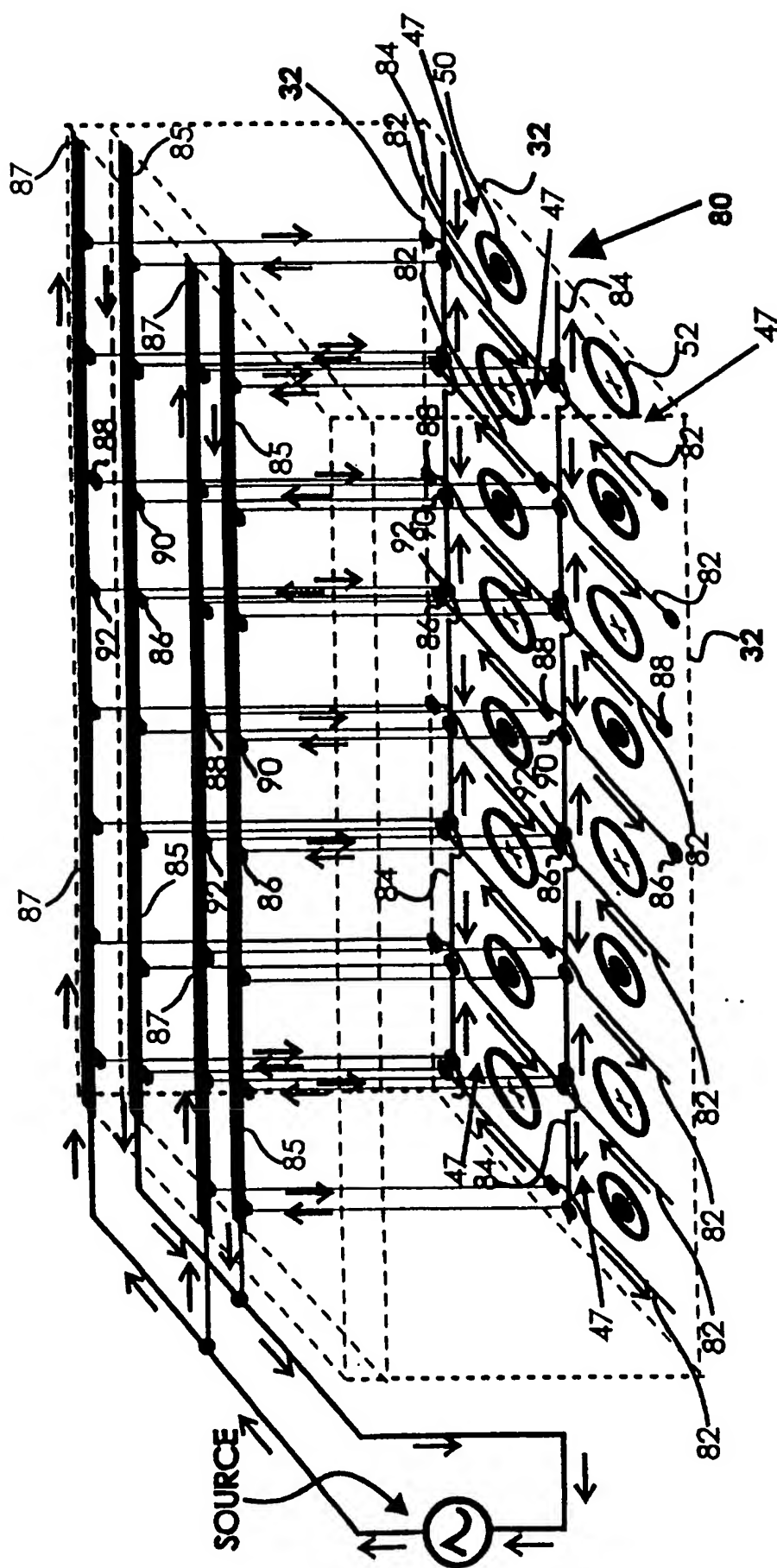


FIG 9C

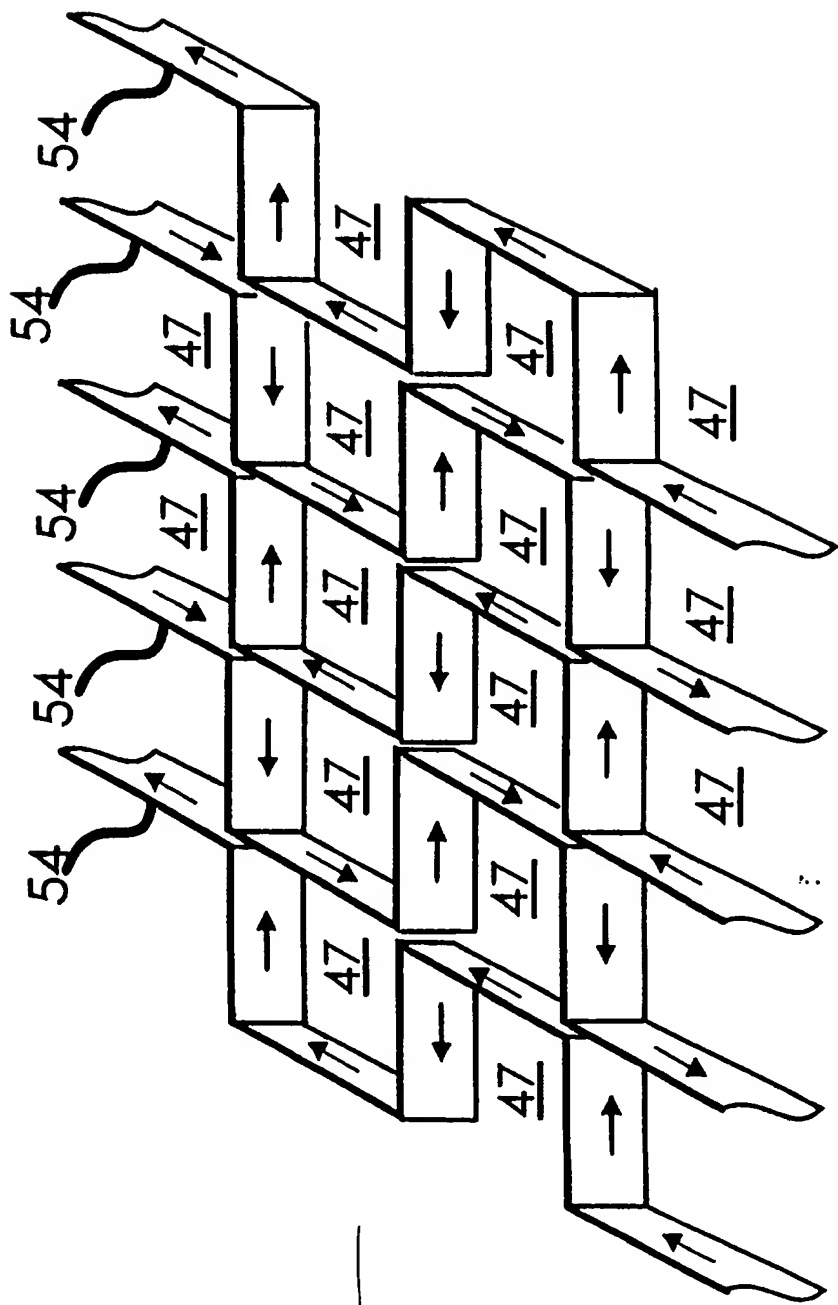


FIG 10

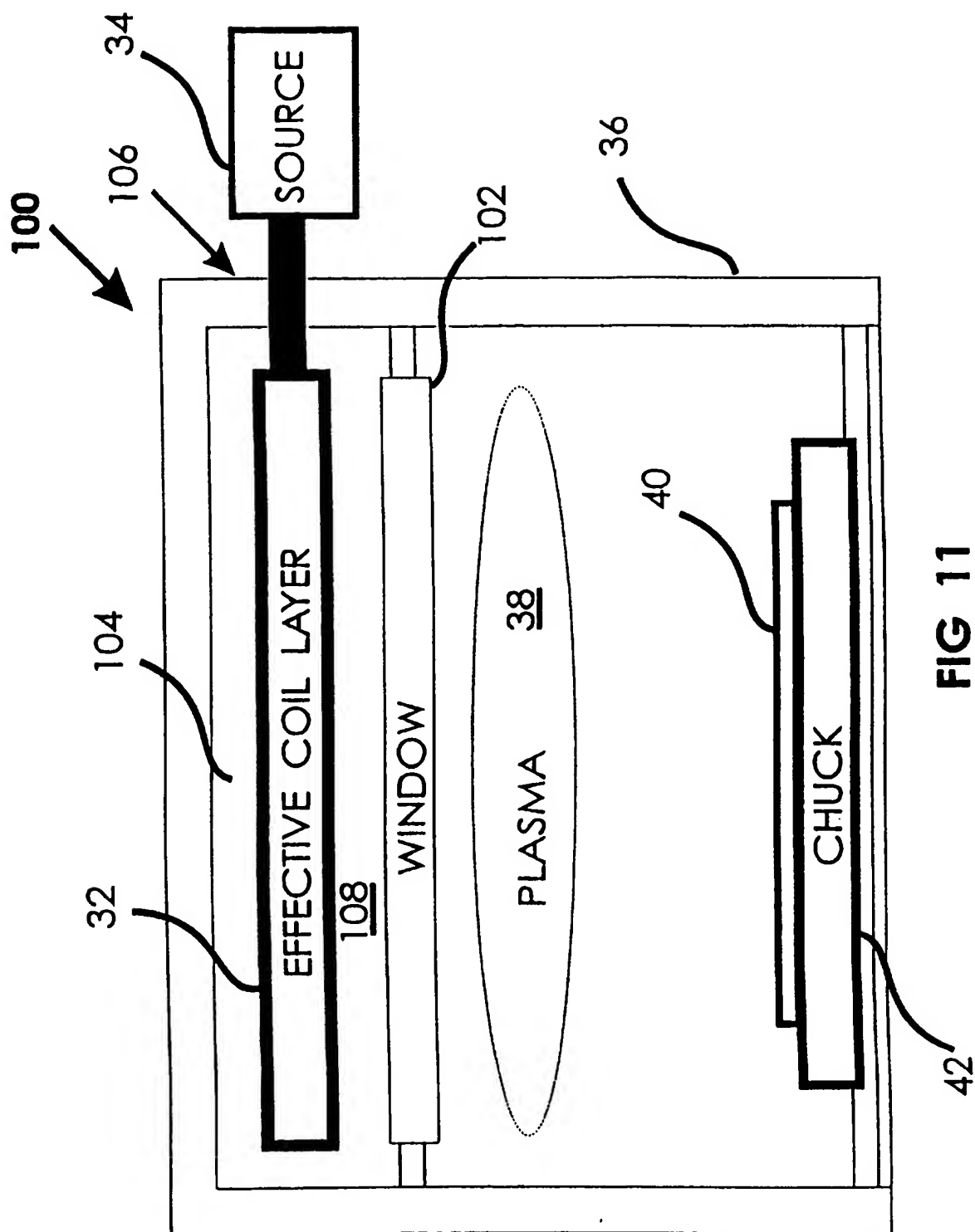


FIG 11

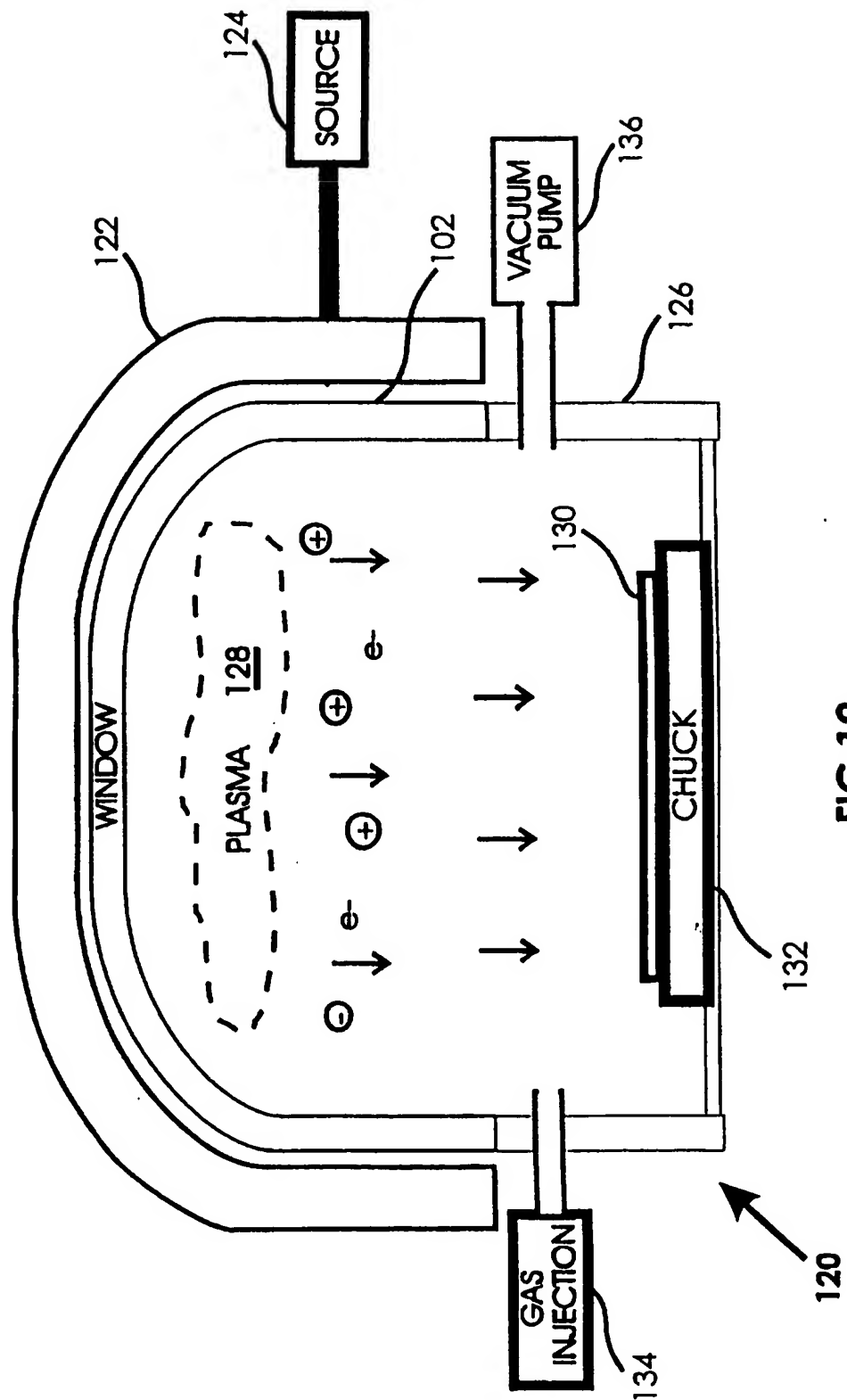


FIG 12

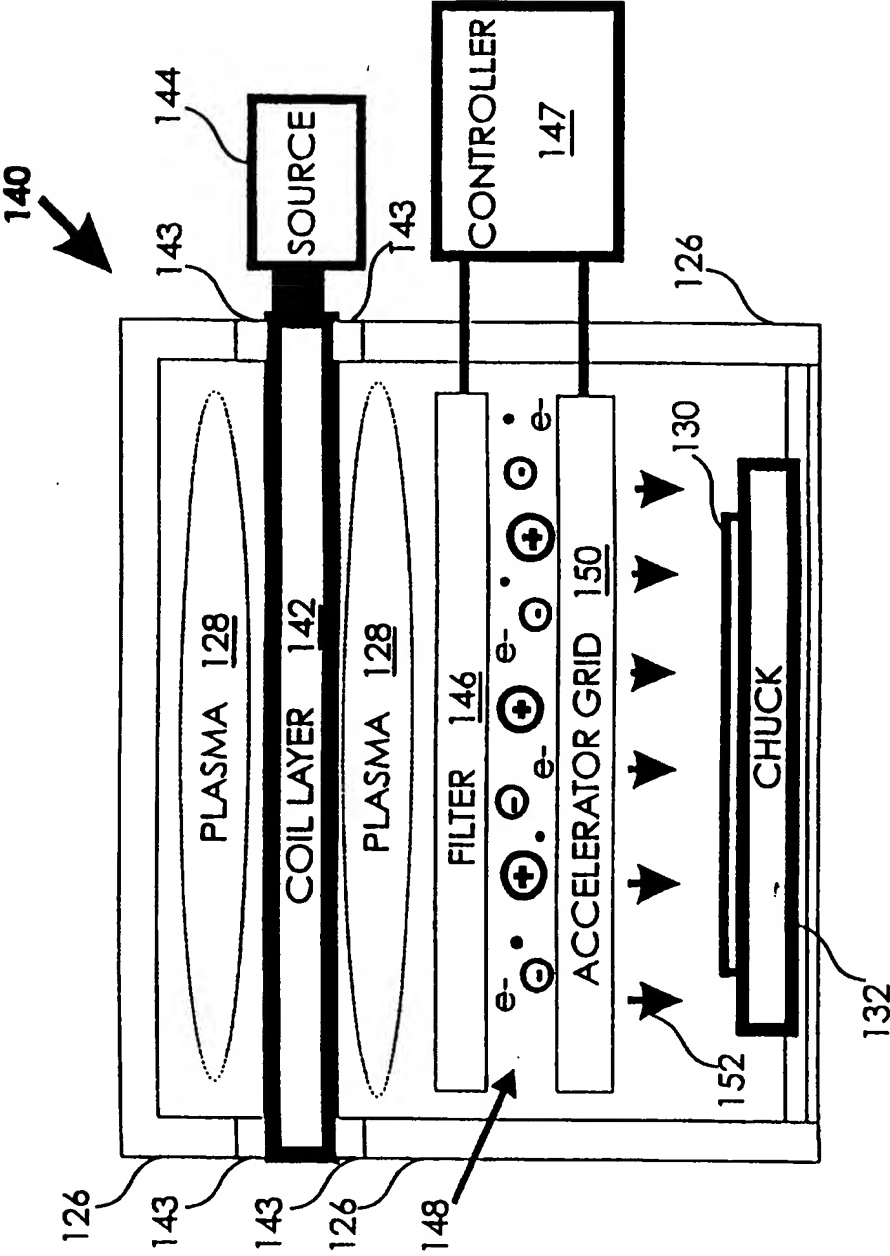


FIG. 13



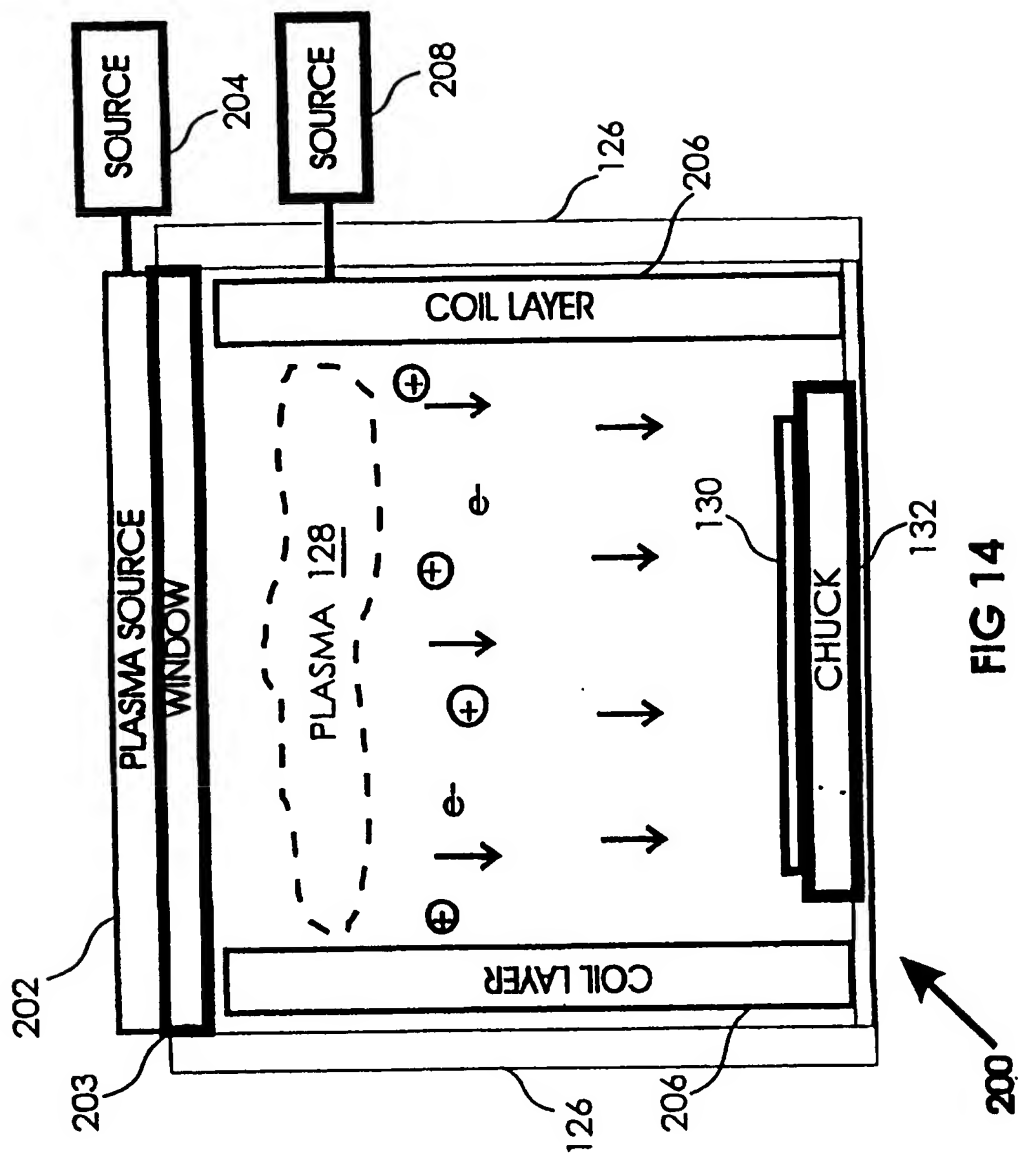
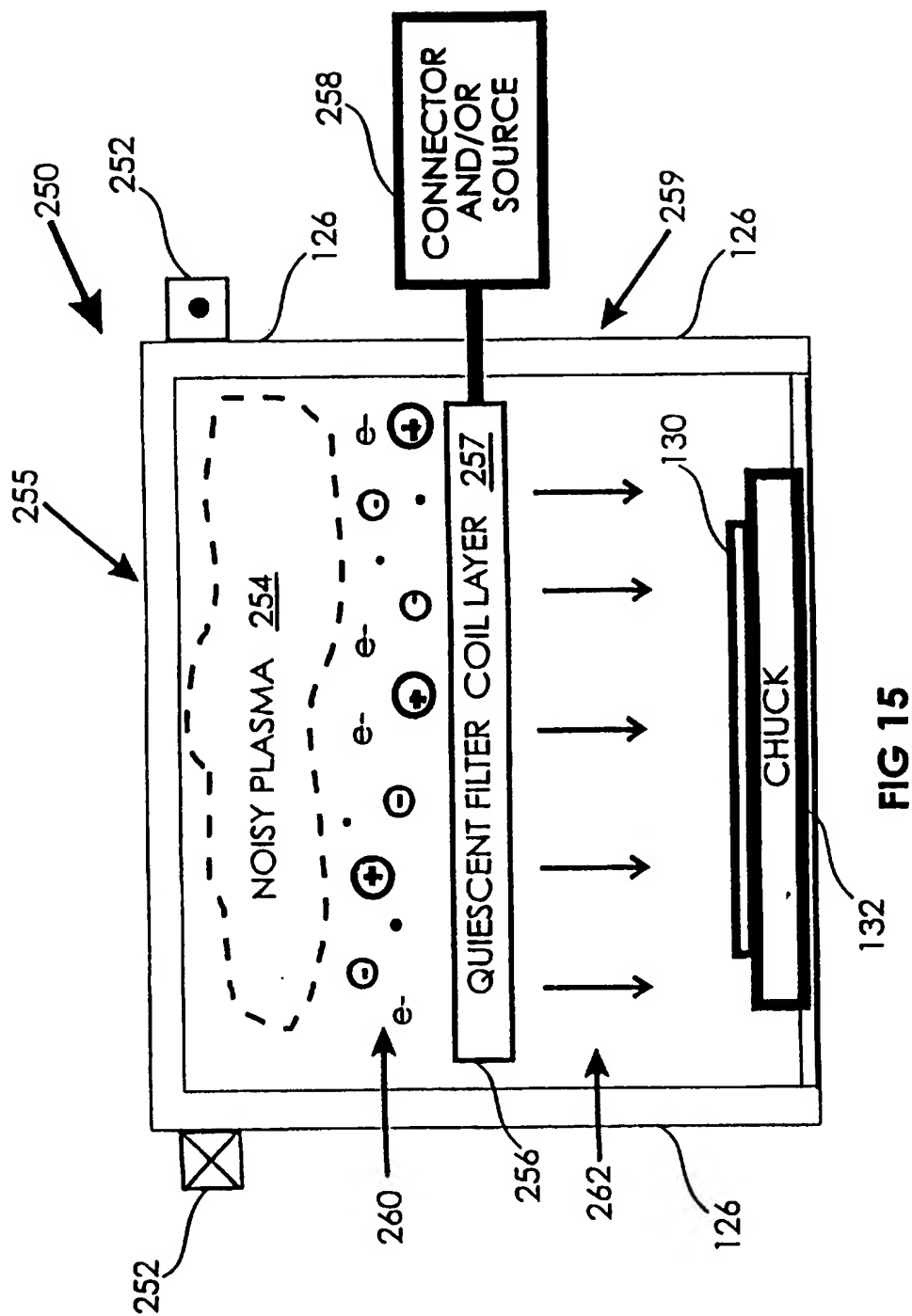


FIG 14



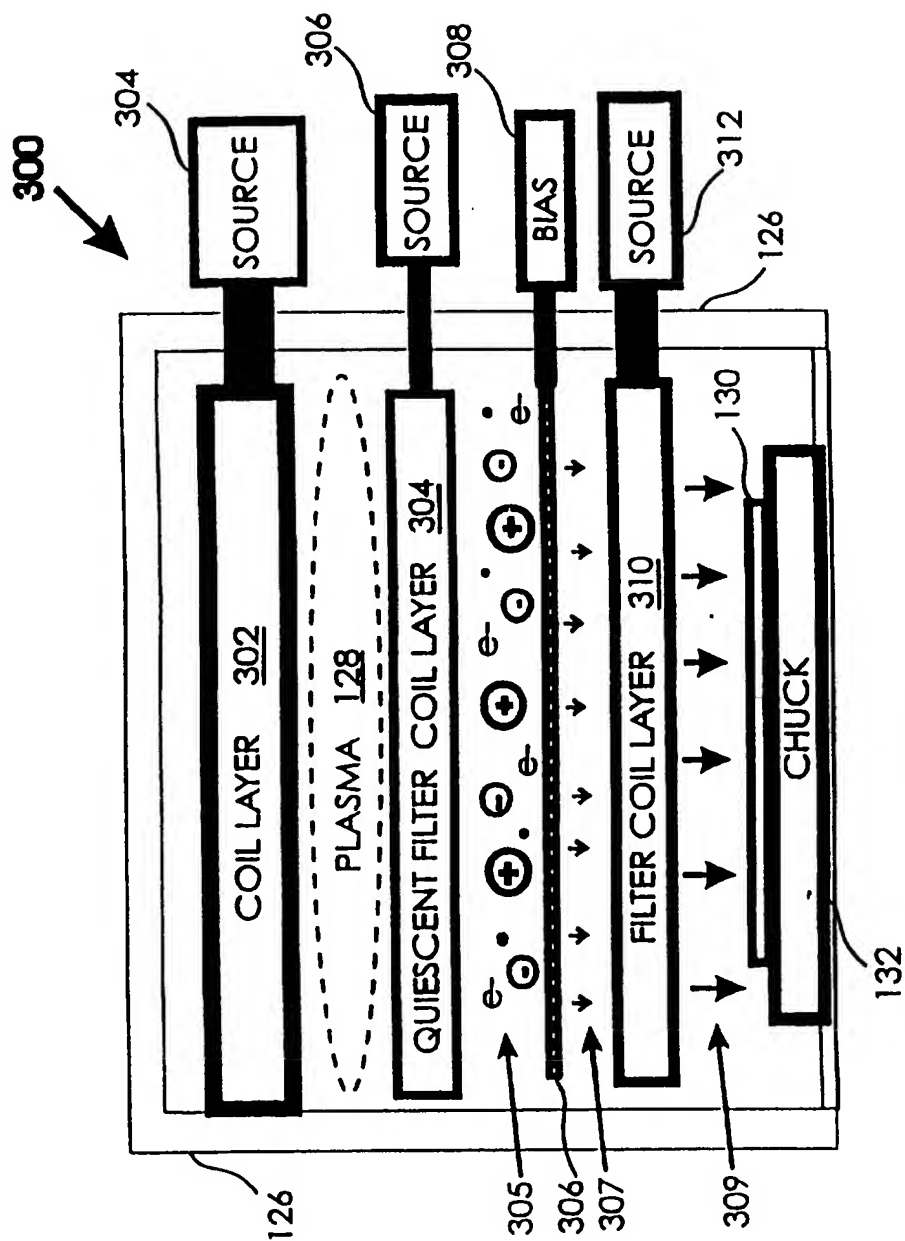
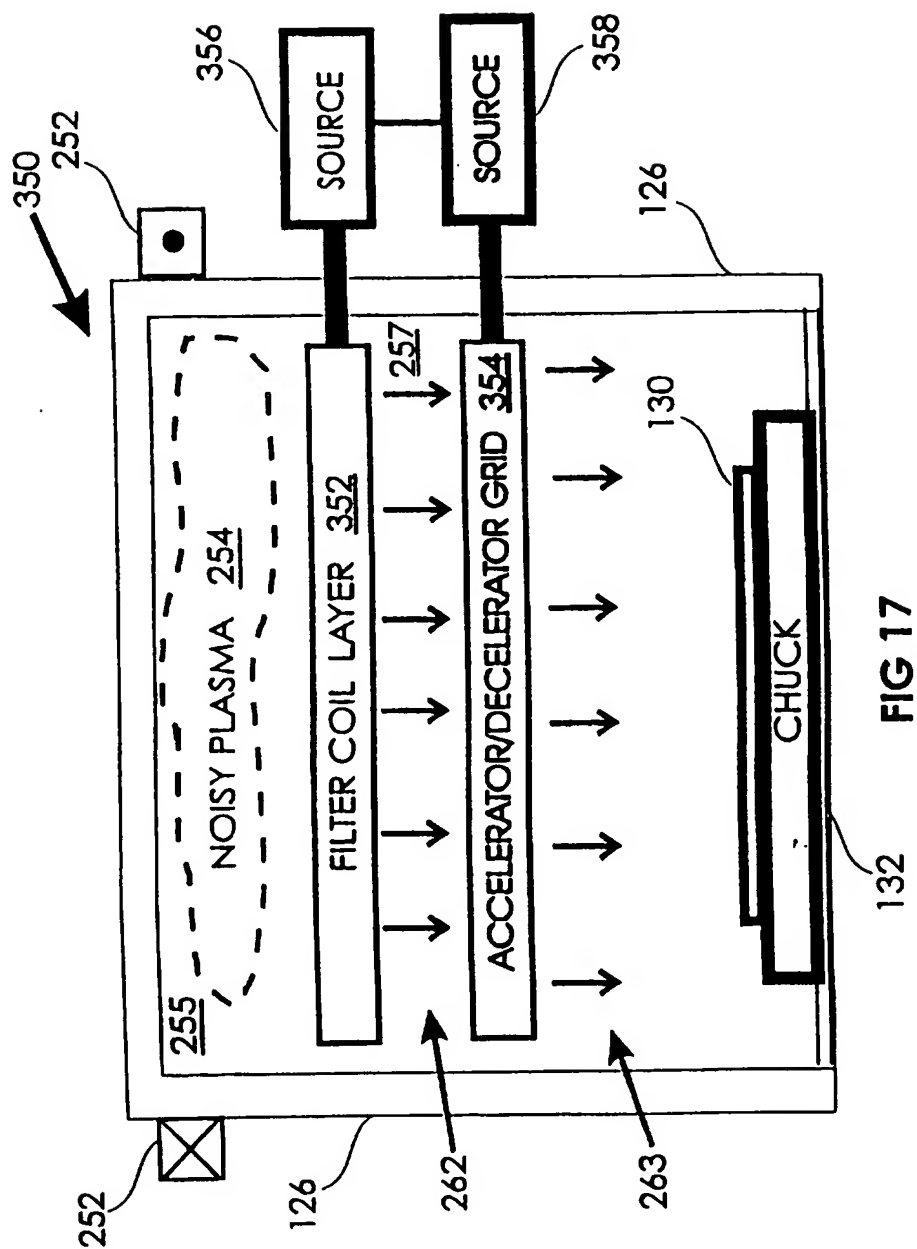


FIG 16



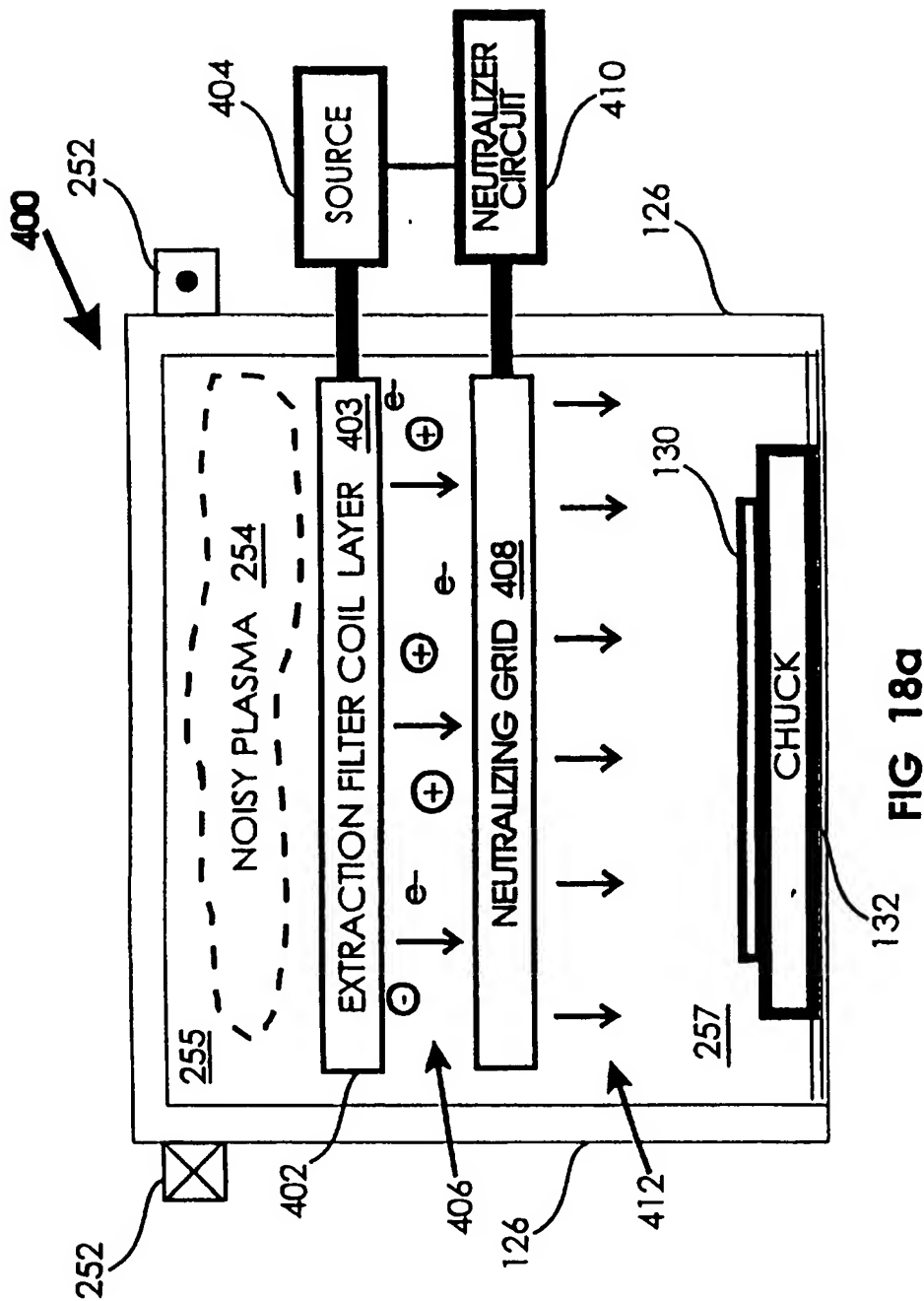


FIG 18a

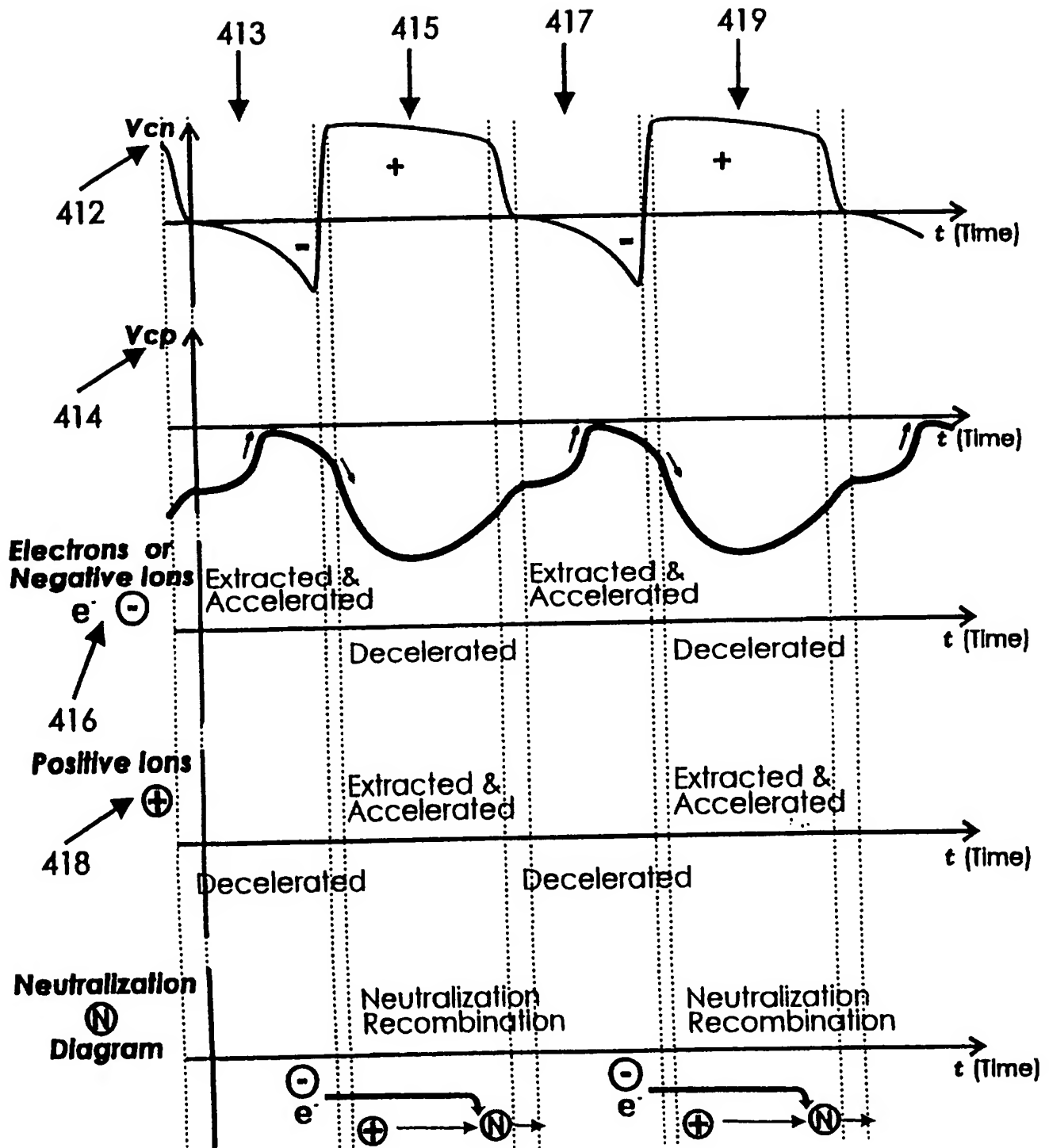


FIG 18b

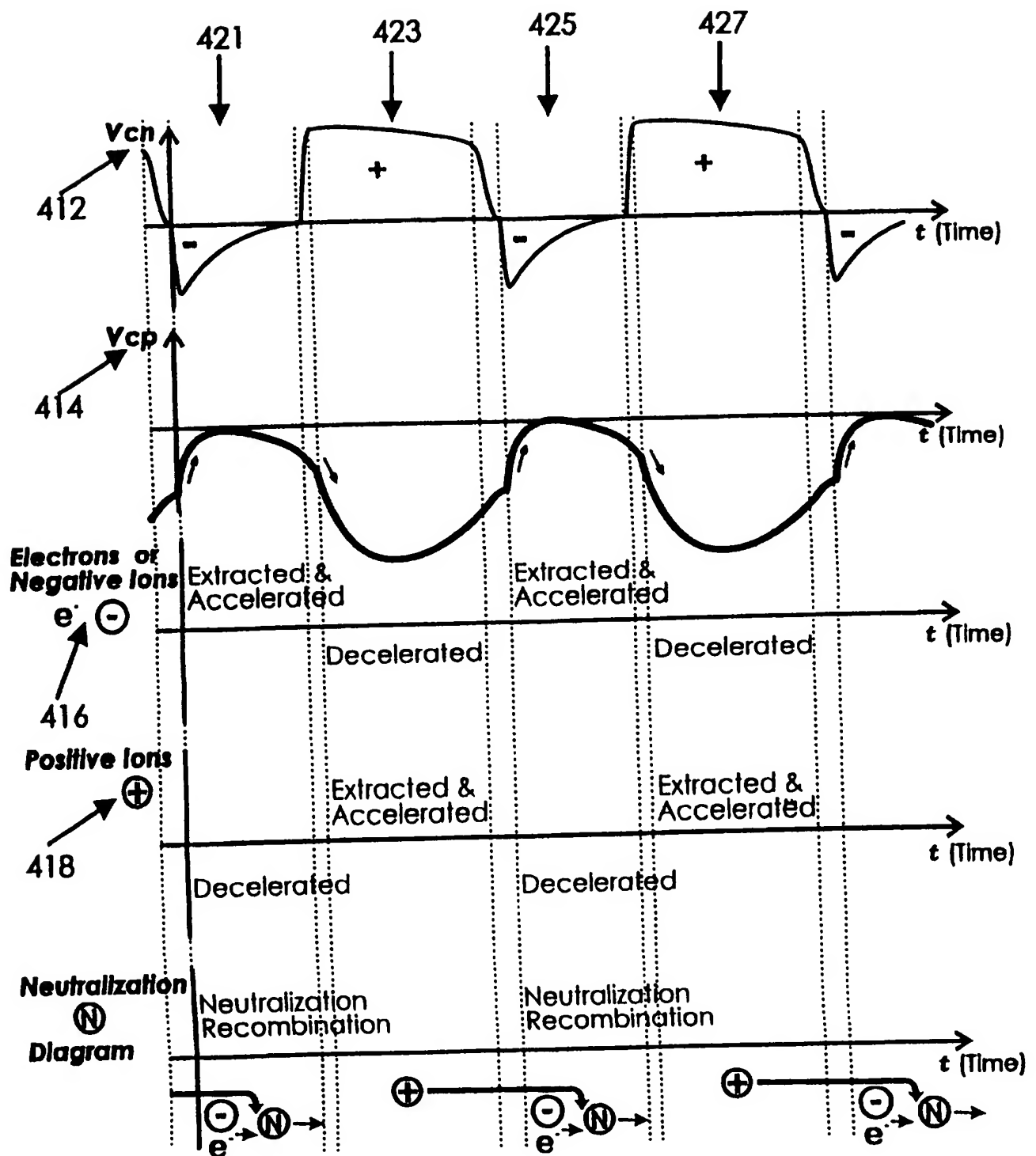


FIG 18c

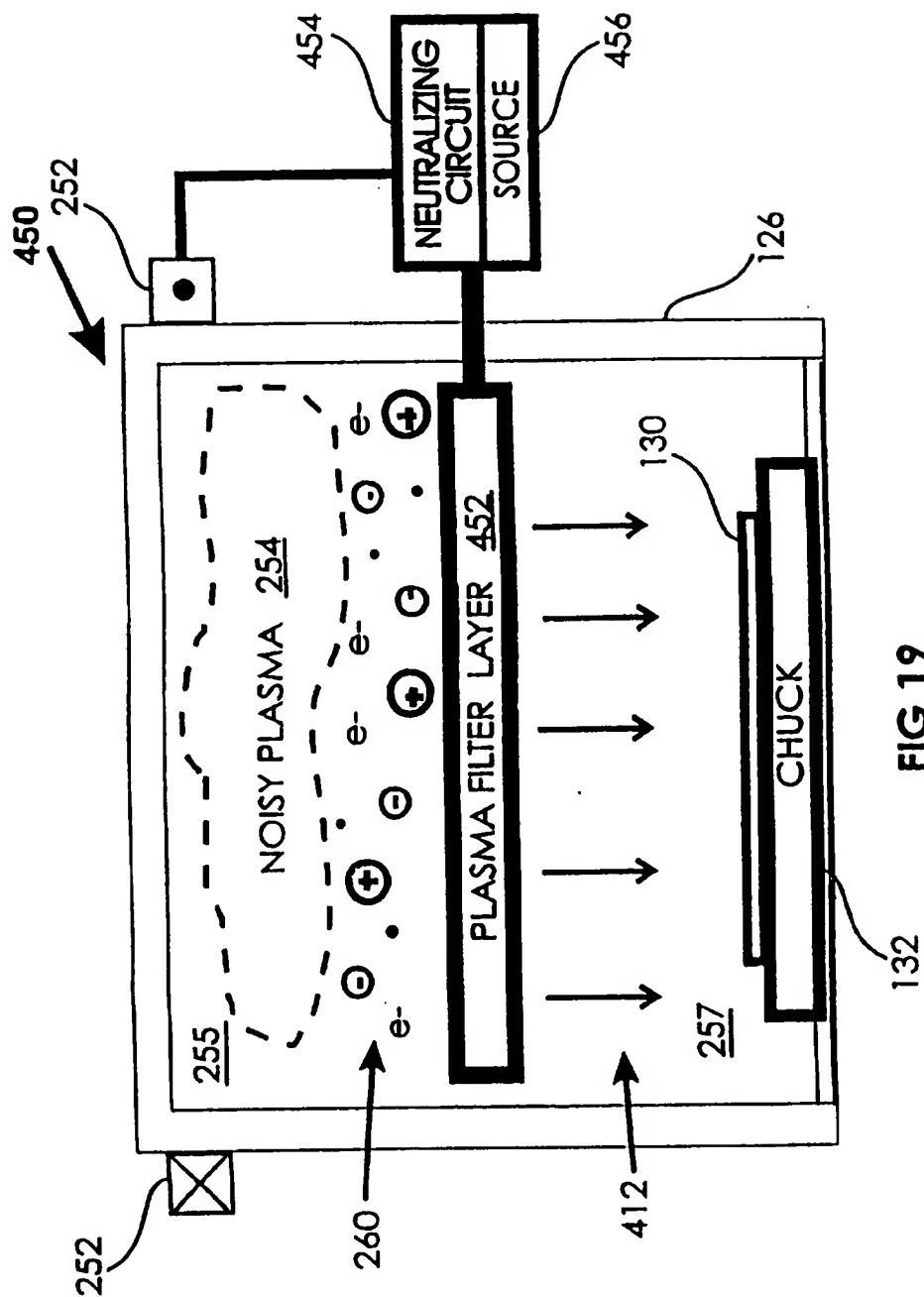
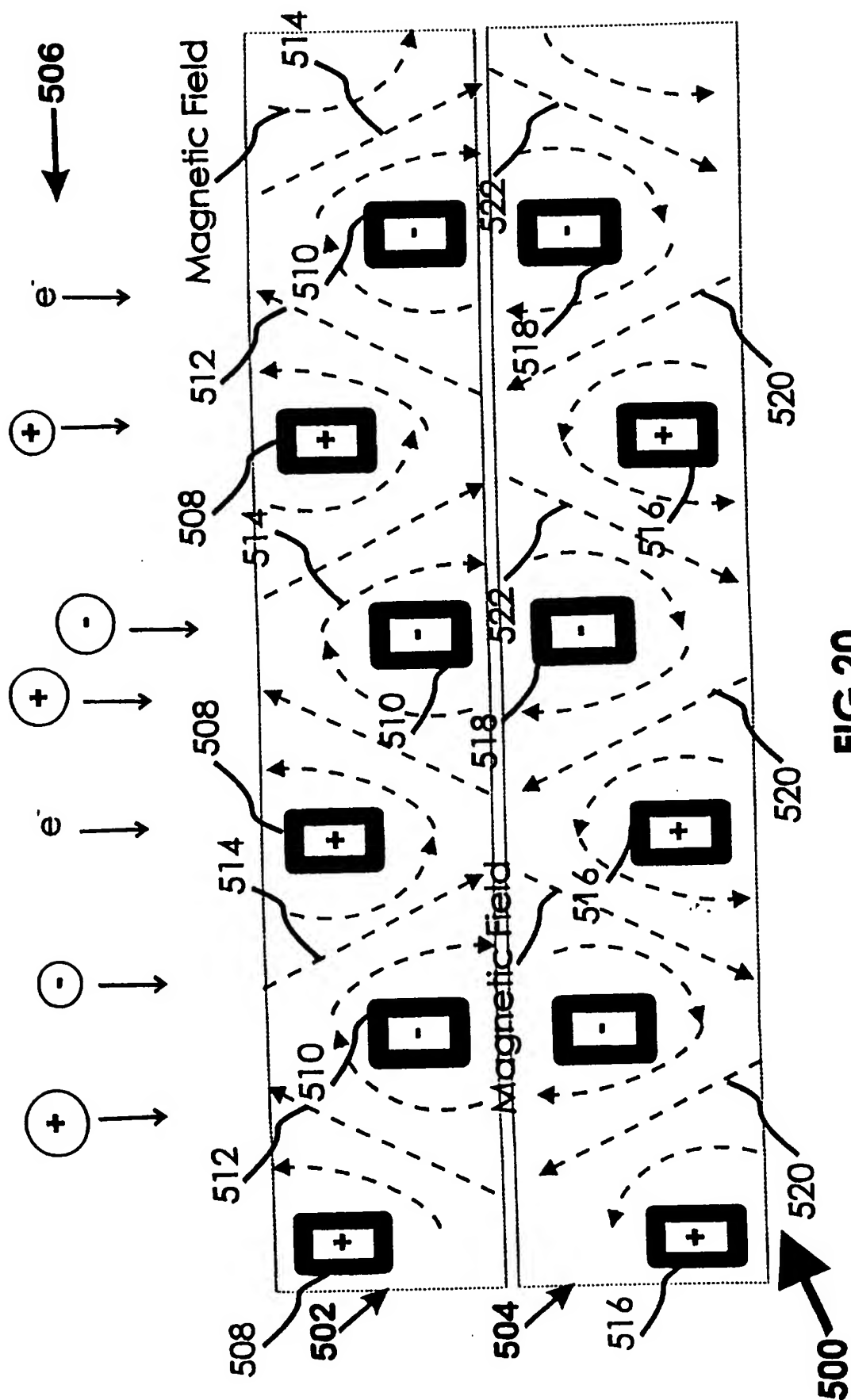
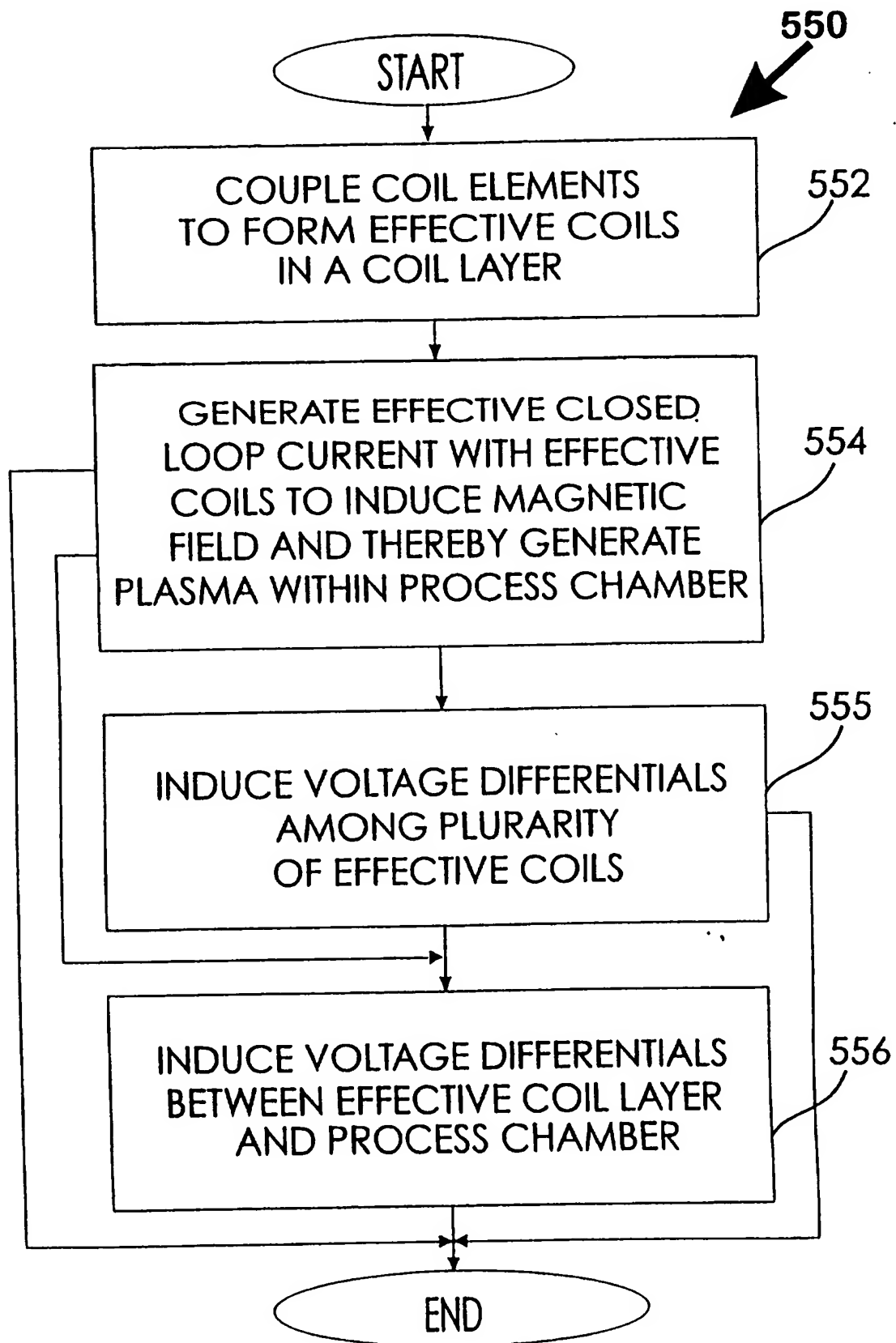
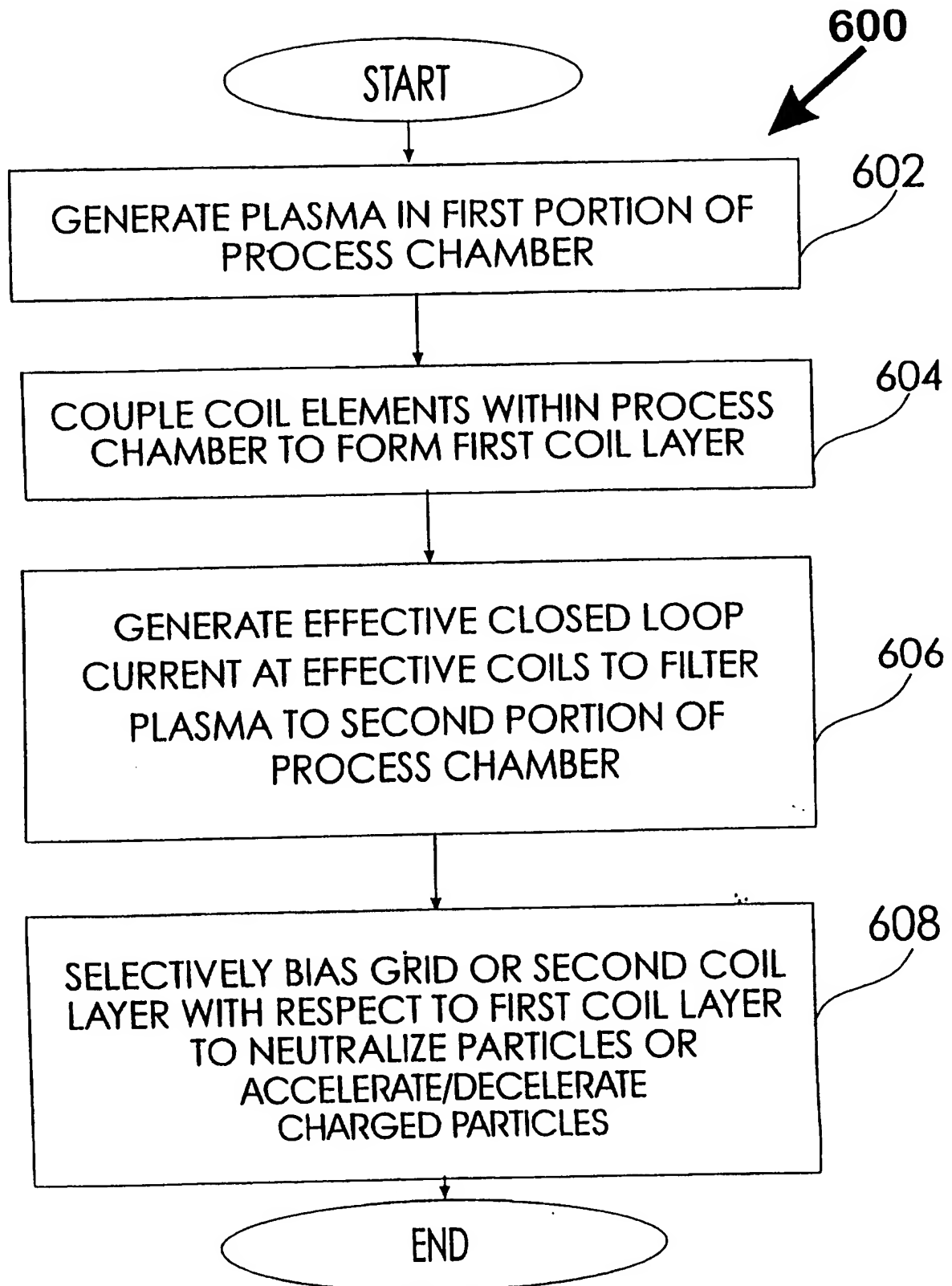


FIG 19





**FIG 21**

**FIG 22**

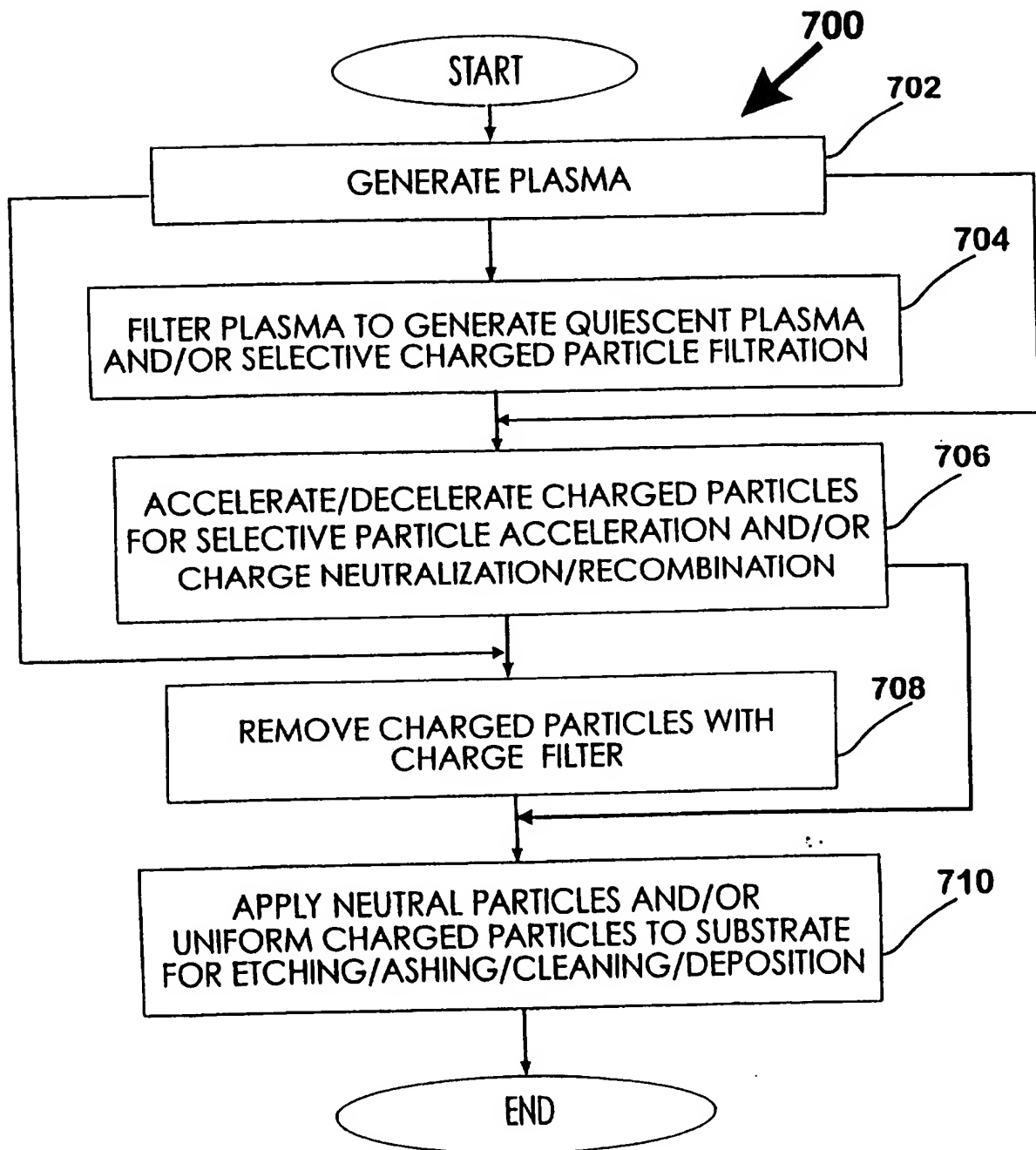


FIG 23

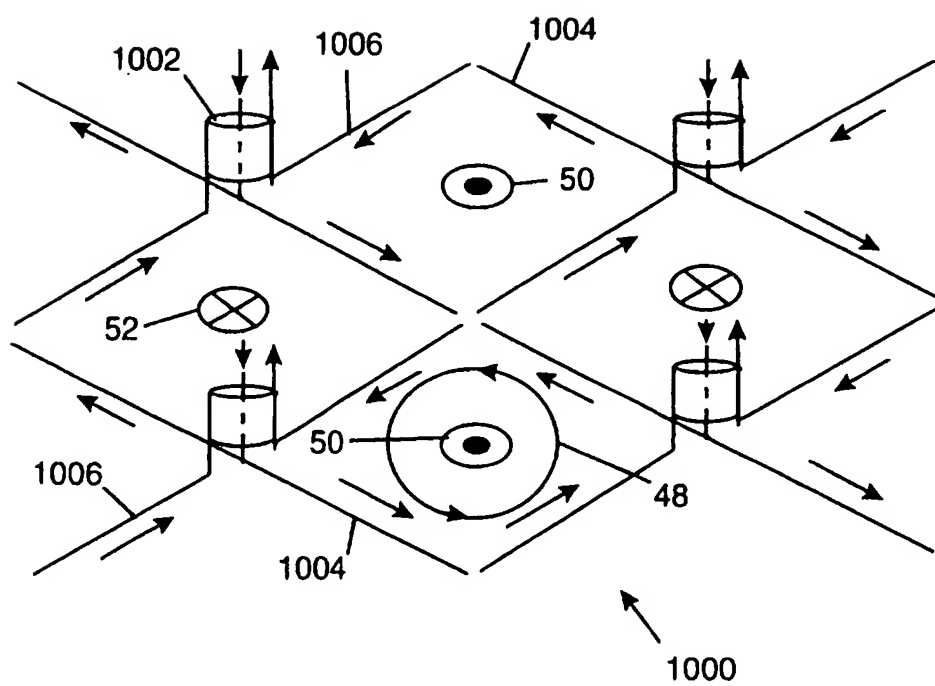


FIG. 24

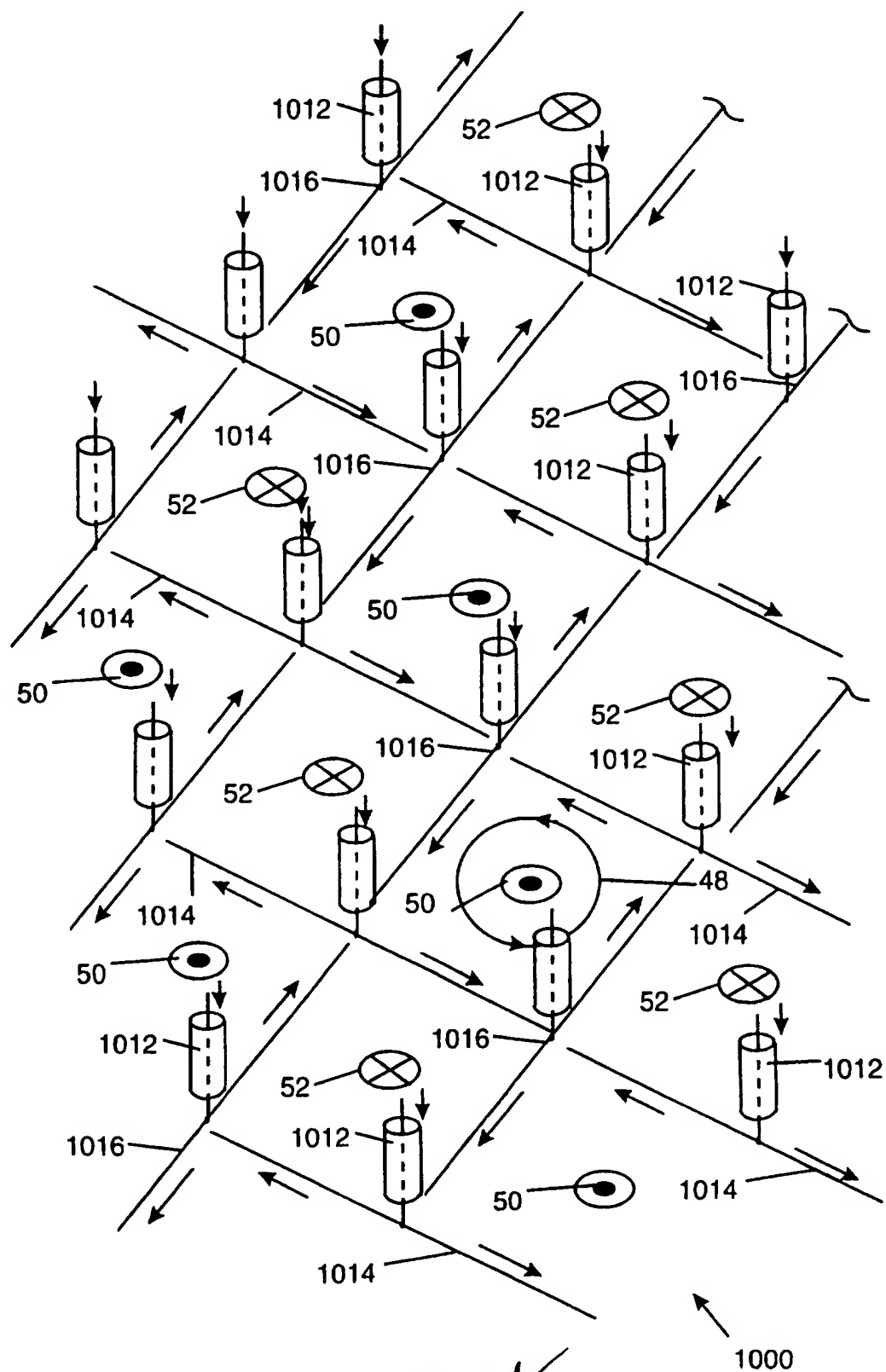


FIG. 25

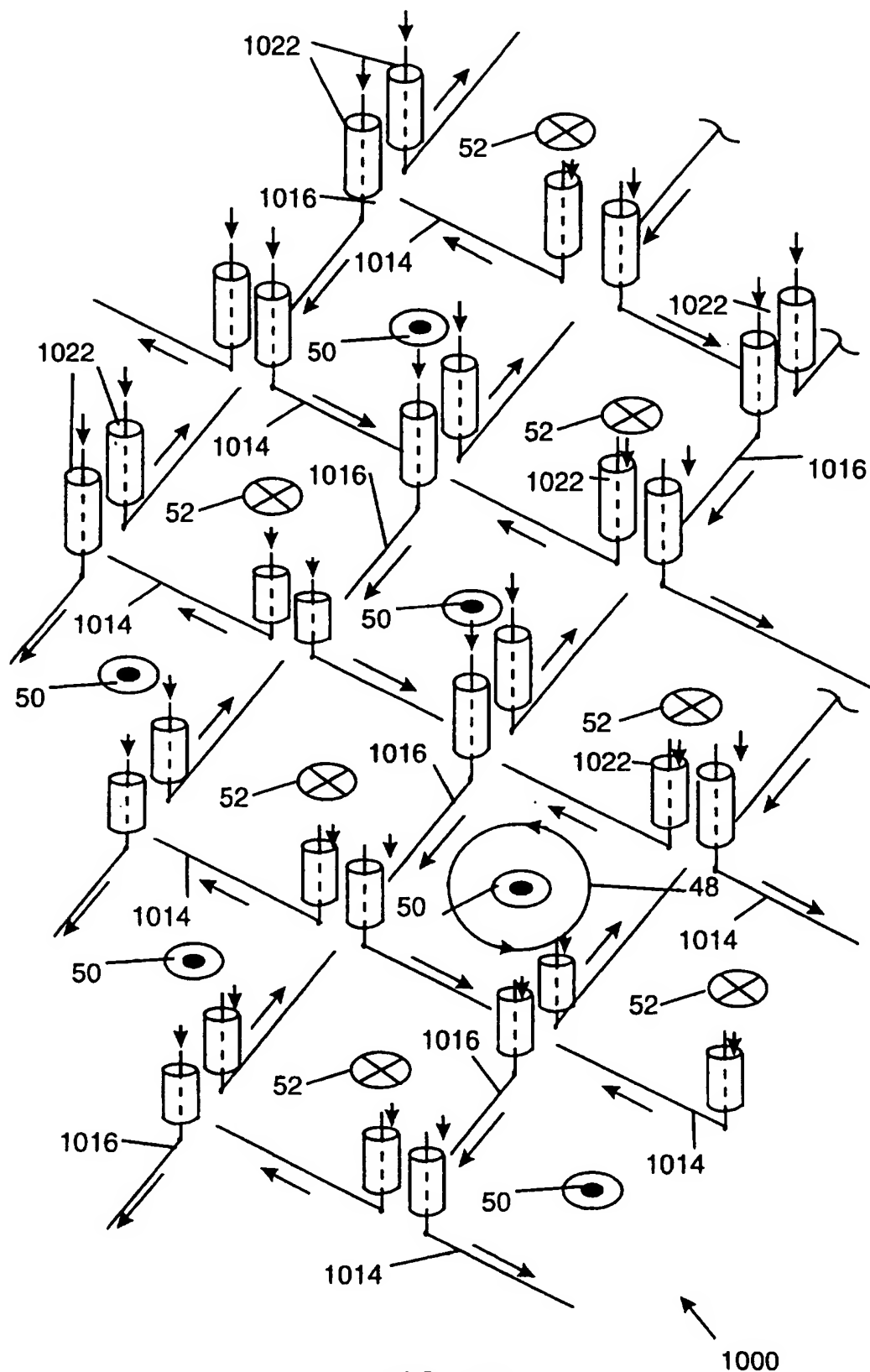


FIG. 26

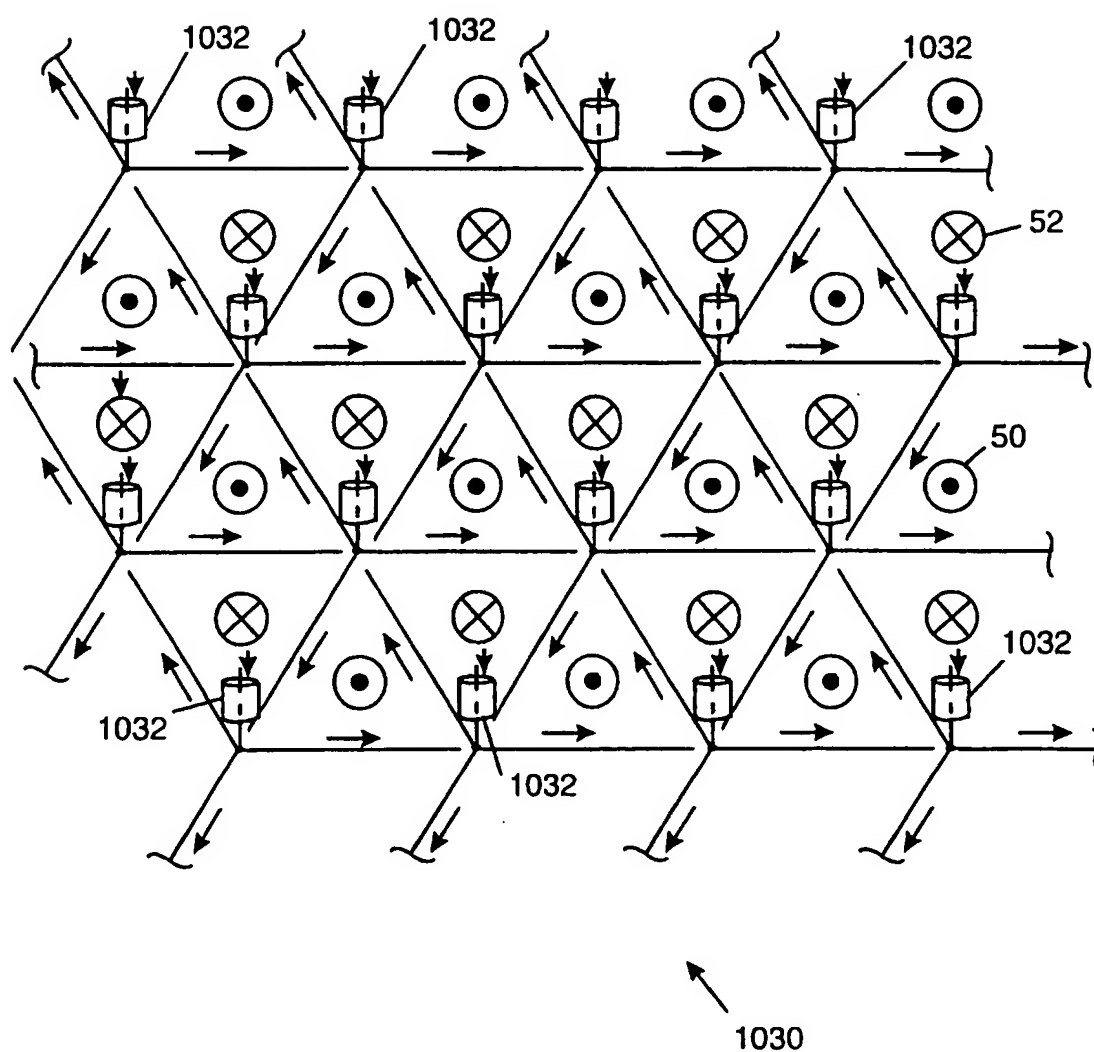


FIG. 27



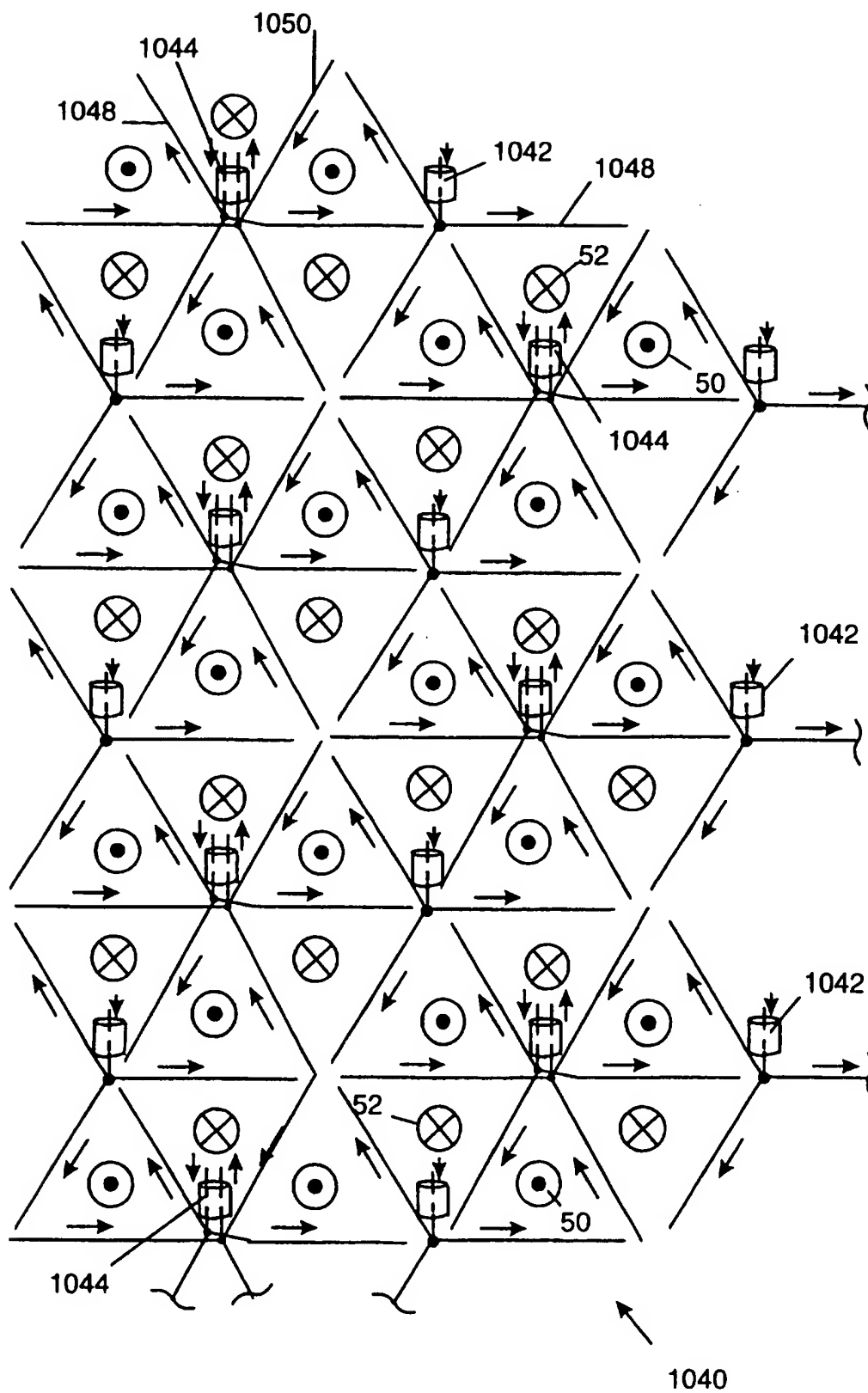


FIG. 28

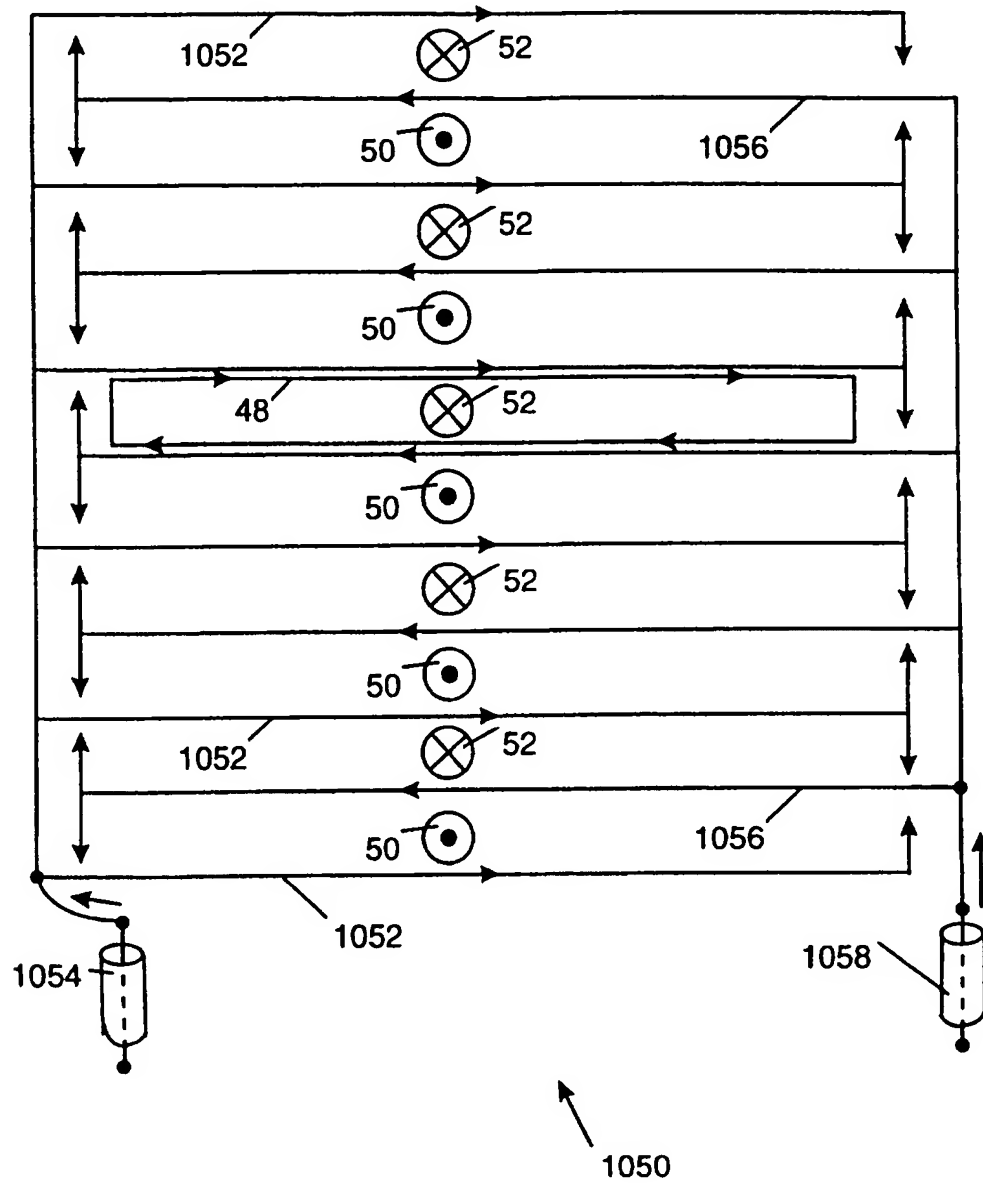


FIG. 29